Report to the Premier

on

Regina - Moose Jaw Water Supply

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PREFACE

This report is not the result of one person's efforts. Many persons and agencies gave freely of their time and knowledge. Hundreds of phone calls and scores of letters were evidence of the widespread concern with the subject. I am most grateful to all of those who contributed in any way to this project.

I am reluctant to single out any one or two groups, but special mention should be made of the contributions from the PFRA and the Saskatchewan Department of Environment. The PFRA reported to me on their preliminary engineering analysis of the many alternatives---a thorough review done in a very short time. The Environment staff provided extensive background information and comment on the subjects of water, water quality, and water treatment.

I have considered all of the information received, and have made made interpretations and selections for this report. I take full responsibility for the statements and recommendations it contains.

Gerald Muirhead, M.L.A.

November 1982.

TABLE OF CONTENTS

		Page
1.	Summary	1
2.	Introduction	7
3.	Water Supply and Demand	13
4.	The Water Quality Problem	23
5.	Alternative Solutions to the Water Quality Problem	33
	Alternative 1: Pipeline to Lake Diefenbaker	35
	Alternative 2: Canal to Lake Diefenbaker	41
	Alternative 3: Regional Water Scheme	44
	Alternative 4: Granular activated carbon contactors	48
	Alternative 5: Pipeline to Qu'Appelle River near Marquis	53
	Alternative 6: Canal to Qu'Appelle River near Marquis	58
	Alternative 7: Detention pond	60
	Alternative 8: Increased Qu'Appelle flow	63
6.	Choosing a Solution	67

APPENDICES

1.	Implementation processes	71
2.	References	77
3.	Letter report on Regina Water Supply by W. A. Meneley Consultants Ltd.	81
4.	Letter report on compounds found in Buffalo Pound Lake by George P. Slater, National Research Council	89
5.	Letter to G. Muirhead, M.L.A. from Dr. D. R. Cullimore, Director of Regina Water Research Institute	97
6.	Buffalo Pound Lake as a source of municipal water	101

TABLES

	PAGE
Table 1 - Water demand key - Existing (1980) demands	14
Table 2 - Water demand key - Projected level I	15
Table 3 - Water demand key - Projected level II	16
Table 4 - Summary of projected water demands	17
Table 5 - Comparison of eight alternatives - after page 70	

FIGURES

1) Alternative 1: Pipeline to Lake Diefenbaker	37
2) Alternative 3: Regional Water Scheme	45
3) Alternative 5: Pipeline to Qu'Appelle River near Marquis	55
4) Effect of Pipeline Diameter on Capital Cost and Present Worth	36

1. SUMMARY

For a short time every summer, the drinking water in Regina and Moose Jaw has an objectionable taste and odour. The problem is well known - in fact it has received national attention. Less well known are the heroic efforts made by the operators of the Buffalo Pound filtration plant to produce a good, safe product from the algae-ridden waters of Buffalo Pound Lake. Chlorination of algae and other organisms, to help in their removal, produces undesirable compounds. The decay of organic material that survives and passes through the filters produces taste and odour. The concentration of harmful substances in the finished water is less than the amounts specified as safe by the province, but there is some unease regarding possible effects of long-term ingestion.

In general, the solution to the problem is to improve the treatment processes, or to get a better supply of raw water. This report considers eight specific solutions that have been developed previously in various reports and are described in the main body of this report. Comments on their effectiveness and cost are drawn from those reports. The solutions are ranked according to the probable quality of the finished water that would be delivered to the cities.

Solution		Annualized cost in[1] millions of dollars
1.	Pipeline from filtration plant to Lake Diefenbaker	17.7
2.	Canal from filtration plant to Lake Diefenbaker	18 (approx.)
3.	Regional water scheme	8.6
4.	Add granular activated carbon to present supply (treatment system)	6.6
5.	Pipeline from filtration plant to Qu'Appelle River north of Marquis	9.8
6.	Canal from filtration plant to Qu'Appelle River north of Marquis	7.3
7.	Add detention pond to present system	3.0
8.	Increase the flow in the Qu'Appelle River	2.9

The gross costs shown here are useful for project comparison. If some projects qualify for various federal and/or provincial grants, their net costs would be less.

Of these eight "solutions", four have been rejected because of residual water quality problems as noted on table 5 and described in the main body of the report. Solution 2 was rejected because the public demand for water from an open canal would probably lead to solution 3 instead.

Of the remaining three, the pipeline to Lake Diefenbaker would provide excellent quality water, but it has the highest cost. The Regional Water Scheme would provide water of good quality at much lower cost. (Although the total cost of a Regional Scheme would be greater than the pipeline, it was assumed that only 20% of the Regional Scheme cost should be allocated to Regina-Moose Jaw supply because they would take approximately 20%

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1. Annual payment required to service debt, operation, maintenance and energy, assuming financing available at 12% and, where applicable, pipe is purchased at the special "cost price" recently offered by IPSCO. Costs are given in 1982 dollars.

of the water). The addition of granular activated carbon contactors to the present system would provide water of acceptable quality at a cost almost equal to the cities' share of the regional scheme.

According to the terms of reference given to me by the Premier of Saskatchewan, I have reviewed several possible solutions to the Regina-Moose Jaw water supply problem, and I recommend unequivocally that the problem be solved by installing a pipeline from Diefenbaker Lake directly to the filtration plant. I have discussed alternatives with many experts and they say that only the pipeline scheme will guarantee (with completion in two years), an excellent quality supply over the long term with minimal operational problems.

The use of Buffalo Pound Lake as a raw water source presents many difficulties, some are related to the technical complexity of achieving adequate water treatment, and some are related to water management problems elsewhere in the Qu'Appelle Valley. More important is the growing public perception that Buffalo Pound Lake is not an acceptable source for human consumption.

I must point out that, according to drinking water quality objectives set by the province, the treated water from Buffalo Pound Lake is safe for human consumption. But I am uneasy about a number of points that have been raised by water-quality experts during my investigation.

- there are several potential sources of taste and odour and, over the long term, treatment facilities and maintenance programs will become more complex in order to handle all of them.
- several chemicals produced by the growth and decay of algae and other organisms will pass through the treatment facilities.
- over the long term, nutrient build-up can be expected in the bed and waters of Buffalo Pound Lake. More nutrients in the treated water may stimulate a potential taste and odour problem in the distribution system after treatment.

In short, none of the experts I contacted during my investigation was prepared to state in writing that treated Buffalo Pound water would be safe at all times for human consumption and free of taste and odour.

Eyebrow Lake, which overflows into the Qu'Appelle and thence to Buffalo Pound Lake, is just one factor in the continuing enrichment of Buffalo Pound Lake. It is rich in minerals from natural run-off. Recently (1981), the waters of that lake killed 1,800 waterfowl. The minerals and bacteria spores are periodically washed downstream along with animal wastes from agricultural operations. No one has quantified the possible long-term effects on Buffalo Pound, but it is another source of concern in respect to water quality for human consumption.

The quality of the water in the canal serving a regional water scheme would deteriorate somewhat en route to the filtration plant, but not nearly to the extent it does now while flowing to Buffalo Pound Lake via the Qu'Appelle River. It would be necessary to exclude local run-off from the canal, to avoid locations where seepage to the canal would add minerals, and to fence the canal to exclude livestock. Frequent maintenance would be necessary to remove weeds. Also, a reservoir near the filtration plant would be needed to provide water in winter. It is thought that algae problems similar to those in Buffalo Pound Lake could be avoided by careful management of water levels, but there is some uncertainty.

A pipeline from Lake Diefenbaker to the filtration plant removes all these uncertainties and potential problems.

In 1957, John Diefenbaker saw beyond the unresolved questions and suggestions for study. He knew it was time for action and said that a dam was to be built on the South Saskatchewan River. Because of his foresight, we have Lake Diefenbaker today, the key water source for Southern Saskatchewan.

Let us do as Winnipeg did in 1916 when they built an eighty-six mile pipeline to the pure waters of Shoal Lake. It was hard to justify then, but it stands today as an extremely wise decision.

By following my recommendation, we will avoid many problems down the road, and avoid the creation of more studies and reports such as we have had almost continuously since 1908.

If a pipeline solution is chosen, there are three ways to implement it. One is to assign the construction, ownership, and operation to an existing Crown Corporation, the Saskatchewan Water Supply Board (SWSB). The Board would deliver the water to the filtration plant, and receive payments from the cities for their allocation portion of the cost. A second way would be to invite the private sector to build, own and operate the pipeline. There would be a premium paid for private sector management because of the spread between interest on government debt and return on private equity. A third way would be to form a public sector-private consortium to handle the project.

If the regional water scheme is chosen, it is likely that Canada would build the main works through PFRA and operate them for an agreed period. Subsequently, the ownership and management of the scheme could be transferred to the SWSB, who would deliver water and collect charges according to the amount of recoverable debt assigned to each use.

If neither of the large schemes is chosen, no new administrative arrangements are needed. Procedures already exist for provincial participation in conventional works through Water Assistance Grants made by the Department of Urban Affairs. These granting procedures could also serve the large schemes if the province did not wish to retain any management role.

Of course I am quite aware that costs of any solution will be a vital consideration and in that regard, I propose to give you further details in respect to finance that may alter the final decision.

II. INTRODUCTION

For more than one hundred years, people have commented on the scarcity of water in southeastern Saskatchewan, the availability of water in the South Saskatchewan River and how the Qu'Appelle Valley connects one to the other. Captain John Palliser, in 1857, envisioned a water transportation route from the South Saskatchewan River, down the Qu'Appelle River, and on to Winnipeg. Professor Hinds, in 1858, suggested a similar scheme with a dam across the river (near the present Gardiner Dam). Sanford Fleming, in 1872, stated that the waters of the South Saskatchewan River could be led easily into the Qu'Appelle.

William Pearce and J. S. Dennis, of the Irrigation Branch, Federal Department of the Interior, followed up those ideas with preliminary surveys in 1896.

In 1911, Mr. T. A. Murray reported to the Saskatchewan Bureau of Health that water supplies were inadequate for Moose Jaw and Regina. He suggested that the Province reserve100,000,000 gallons per day of South Saskatchewan River water for eventual use in Regina and Moose Jaw. In the same year, a similar recommendation was made by W. J. Francis and that summer the first of many investigations began.

1911	Survey of possible diversion routes by Ben Russel, Federal Department of the Interior.
1912/13	Survey of pipeline routes and damsites by Montague and Burley, Department of Interior.
1913	Study and report on diversion of 100,000,000 gallons per day to Moose Jaw and Regina; Kensit, Superintendant of Water Power, Department of Interior.
1920	A Provincial Commission (A. J. MacPherson) reported that 12 to 16 million gallons per day could be directed to Moose Jaw, Regina, and surrounding areas. The matter was to be voted upon and financed by debentures.

Interest waned for a few years until Moose Jaw encountered a crisis when its groundwater supply failed in 1937. PFRA constructed a pumping plant and canal from the South Saskatchewan River near Riverhurst to recharge the city's main well field at Caron. The scheme was expensive to operate, and when in the 1950's, Regina could forsee similar problems, Moose Jaw agreed to a joint scheme for the use of Buffalo Pound Lake as a raw water source. The Province contributed financial assistance for the treatment plant and pipelines, and authorized a diversion of up to 100,000,000 acre feet per year from the South Saskatchewan River. The Federal Government agreed to take whatever action was necessary to ensure that water would be available in Buffalo Pound Lake (it had gone completely dry in the thirties). The cities began using this new supply in 1955. Shortly afterwards, the Federal Government built a 100 cfs. pumping plant (53.9 mgd or 2.8 M^3/sec) at Elbow and a canal to the Qu'Appelle River to convey South Saskatchewan River water to Buffalo Pound Lake. The pumping scheme was no longer needed when, in 1968, Diefenbaker Lake filled and releases of water could be made directly into the Qu'Appelle River.

With the creation of Diefenbaker Lake, there was renewed interest in water distribution to the dry south. Three of the more important investigations were:

1965: Preliminary study of Conveyance Route - South Saskatchewan Reservoir to Filtration Plant near Buffalo Pound Lake - PFRA internal report.

1966: Possible Canal Route - Qu'Appelle Valley to Souris River Watershed - by R. Rodgers of the Investigation and Planning Branch of the Saskatchewan Water Resources Commission (internal report).

1967: Proposed study of Water Supply to the Regina Area - by the Investigation and Planning Branch of the Saskatchewan Water Resources Commission (internal report).

Meanwhile, the Buffalo Pound Water Administration Board (established by Regina and Moose Jaw to run the treatment plant) had its hands full. Each summer the algae and other organisms flourished in the fertile waters of Buffalo Pound Lake. As the volume of water delivered to the cities increased, the production of high quality drinking water became more difficult. Expansion of conventional treatment facilities was not doing the job. Objectionable taste and odour was a recurring problem every summer. The public complained loudly. In April 1980, the Buffalo Pound Water Administration authorized a consultant to study possible modifications to the existing water treatment facilities that would yield a better quality water. The consultant (1)[1] recommended the installation of activated carbon adsorption facilities to control taste and odour. The required capital and annual expenditures were substantial.

Early in 1981, Regina and Moose Jaw requested provincial financial assistance for implementing an immediate solution tothe taste and odour problem. A Steering Committee was established (representing Moose Jaw, Regina, Province of Saskatchewan and the Government of Canada) to identify water supply alternatives or combinations of alternatives "which may be capable of providing sufficient water of acceptable quality to meet projected water demands to the year 2030". Their report (2), completed in February 1982, put forward four alternatives:-

1) existing system with addition of granular activated carbon treatment;
or 2) Buffalo Pound Lake by-pass (pipeline or canal);
or 3) pipeline direct from Lake Diefenbaker to filtration plant;
or 4) multi-purpose water supply scheme from Lake Diefenbaker.

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1. Throughout the report, references are indicated by numbers in parenthese. The text of references is given in Appendix 2.

The Steering Committee recommended further study of these four alternatives, but Regina and Moose Jaw felt that the public was demanding an early solution. They wrote to the Ministers of Urban Affairs and Environment on August 11, 1982, requesting provincial financial assistance in the construction of facilities for granular active carbon treatment and also in proceeding with a Phase II study of long-term solutions.

Meanwhile, because of the recession, the Interprovincial Steel Company said that it would supply pipe at cost for a pipeline from Lake Diefenbaker to Buffalo Pound Lake. At the same time, some scientific questions arose as to the exact cause of the taste and odour, and the effectiveness of granular activated carbon treatment to remove them. These events led to a September 15, 1982, letter from the City of Regina to the Premier of Saskatchewan requesting provincial participation in the pipeline project. On September 9, 1982, Moose Jaw put forward a similar request to the Prime Minister of Canada with copies to the provincial government members.

Early in July 1982, the Premier had instructed Gerald Muirhead, M.L.A., to study and report on the broad question of water policies and programs in Saskatchewan. When the request from the cities was received, he referred it to Mr. Muirhead for report according to the following terms of reference:

" 1) to review all information with respect to the adequacy of and alternative to, existing water supply and treatment for the communities of:

a) Regina b) Moose Jaw c) Moose Jaw Air Base d) all other nearby municipalities and major water users which are presently connected or could reasonably be served in future through shared water supply and treatment with Regina and Moose Jaw municipalities.

2) to assess the adequacy of the existing Regina/Moose Jaw water supply with respect to both current and long-term uses, including, but not necessarily limited to:

   a) the adequacy of water quantity to meet projections of future demand;

   b) the adequacy of current and projected drinking water to protect the health and safety of local residents;

   c) the adequacy of other water quality characteristics related to aesthetics, hardness and any other relevant water quality considerations.

   d) the relative magnitude and significance of the Regina/Moose Jaw water supply problems in the context of other similar problems and concerns documented elsewhere in Saskatchewan, as well as other provincial water management issues.

3) to identify and evaluate alternative options for resolving the Regina/Moose Jaw water supply problems identified in 1) and 2) above including:

   a) delivery from alternative sources of new water supply;

   or b) alternative methods of delivery allocation and/or treatment of water from existing raw water sources;

   or c) combinations among alternative categories a) and b).

4) to make recommendations respecting an appropriate method or methods for solving the Regina/Moose Jaw water supply problem, as well as:

   a) a recommended process for project implementation;

   b) the relative responsibilities (technical and financial) to be assumed by the three levels of government - municipal, provincial, and federal;

   c) the need for follow-up research and study."

III. WATER SUPPLY AND DEMAND

Present and Future Demand

The future water needs of Regina and Moose Jaw have been estimated by the Steering Committee (2). The Committee also examined future water requirements in the region that might be served, in whole or in part, directly or indirectly by Regina/Moose Jaw water schemes. They looked at the needs of other communities, industry, recreation and wildlife, and agriculture. The results of their forecasts are contained in table 1, for existing demands, and tables 2 and 3 for year 2030 demands - one assuming a low rate of growth and one high. The most probable forecast lies somewhere between tables 2 and 3. A summary of their forecasts is given in Table 4.

Present Supply System

Regina draws about one-third of its total current demand from twenty-five wells in the Regina aquifer system. The balance of its requirements and all of Moose Jaw's requirements are served from the filtration plant that draws raw water from Buffalo Pound Lake.

The outlet of the lake has been dammed and, since 1959, water has been diverted into the lake from the South Saskatchewan River. In its natural state, Buffalo Pound Lake would not be able to supply Regina and Moose Jaw because, in dry years the natural run-off coming into the lake from the Upper Qu'Appelle River is not sufficient to replace evaporation losses.

The Qu'Appelle River channel from Lake Diefenbaker to Buffalo Pound Lake has been improved to carry a flow, under ideal conditions, of 11.3 m^3/sec (400 cfs). However the channel capacity (3) is reduced by weed growth in mid-summer and by ice in winter to about 8 m^3/sec and 1.4 m^3/sec respectively. Even so, the potential flow is sufficient to ensure a supply in Buffalo Pound Lake that would meet Regina and Moose Jaw demands in the year 2030 and beyond.

Table 1

WATER DEMAND KEY - EXISTING (1980) DEMANDS

Demand Source	Total 1980 Demand (dam^3)
Municipal	
City of Regina	31,230*
City of Moose Jaw	7,000**
Filtration Plant Losses	3,800
Other Communities	Negligible
Industrial	
Kalium Chemicals Ltd.	5,550
Recreation and Wildlife	
Qu'Appelle R. (Buffalo Pound & Upstream)	1,400***
Qu'Appelle R. (Buffalo Pound to Craven)	25***
Qu'Appelle R. (Craven to Manitoba Boundary)	445***
Wascana Creek Basin	1,100
Moose JawRiver Basin	125
Agricultural (Irrigation)	
Along Qu'Appelle R. (Buffalo Pound & Upstream)	500
Along Qu'Appelle R. (Buffalo Pound to Craven)	2,000
Along Qu'Appelle R. (Craven to Manitoba Boundary)	5,000

* Peak day factor = 2.0

** Peak day factor = 2.6

*** Figures do not include provision for maintaining lake levels at desirable levels. Releases near maximum channel capacity were made during April-August 1981 for the first time in an attempt to enhance downstream water levels. A total of approximately 143,000 dam^3 was released.

Note: 1 dam^3 = 1,000 cubic metres = 0.81 acre feet

TABLE 2

WATER DEMAND KEY - PROJECTED LEVEL I

Demand Source	Quantity Required by Year 2030 (dam^3)		
	Summer	Winter	Total Annual
Municipal			
City of Regina	27,000	21,000	48,000
City of Moose Jaw	7,700	4,000	11,700
Filtration Plant Losses	3,500	2,500	6,000
Other Communities			Negligible
Industrial			
Kalium Chemicals Ltd.	2,800	2,800	5,600
S.P.C. Thermal Power Plant	-	-	-
Potash Corporation of Saskatchewan	-	-	-
Sask. Oil - Upgrader	-	-	-
Recreation and Wildlife			
Qu'Appelle R. (Buffalo Pound & Upstream)	14,450 *	50	14,500
Qu'Appelle R. (Buffalo Pound to Craven)	82,000 *	-	82,000
Qu'Appelle R. (Craven to Manitoba boundary)	31,500 *	-	31,500
Wascana Creek Basin	5,000	-	5,000
Moose Jaw River Basin	300	-	300
Agricultural (Irrigation)			
Along Qu'Appelle R. (Buffalo Pound & Upstream)	30,000	-	30,000
Along Qu'Appelle R. (Buffalo Pound to Craven)	24,000	-	24,000
Along Qu'Appelle R. (Craven to Manitoba boundary)	28,000	-	28,000
Along Orange Route**	54,000	-	54,000
Along Green Route** (Includes 140,000 dam^3 diversion to Souris Basin)	205,000	-	205,000
Red Route South of Craven** (Includes 140,000 dam^3 diversion to Souris Basin)	192,000	-	192,000

* Includes make-up for evaporation from lakes.
** Refer to Reference (2)

Note: 1 dam^3 = 1,000 cubic metres = 0.81 acre feet

TABLE 3

WATER DEMAND KEY - PROJECTED LEVEL II

Demand Source	Quantity Required by Year 2030 (dam^3)		
	Summer	Winter	Total Annual
Municipal			
City of Regina	34,500	27,000	61,500
City of Moose Jaw	9,900	5,100	15,000
Filtration Plant Losses	4,500	3,000	7,500
Other Communities			Negligible
Industrial			
Kalium Chemicals Ltd.	2,800	2,800	5,600
S.P.C. Thermal Power Plant	8,700	8,700	17,400
Potash Corporation of Saskatchewan	8,300	8,300	16,600
Sask. Oil - Upgrader	3,300	3,300	6,600
Recreation and Wildlife			
Qu'Appelle R. (Buffalo Pound & Upstream)	14,450 *	50	14,500
Qu'Appelle R. (Buffalo Pound to Craven)	82,000 *	-	82,000
Qu'Appelle R. (Craven to Manitoba boundary)	31,500 *	-	31,500
Wascana Creek Basin	5,000	-	5,000
Moose Jaw River Basin	300	-	300
Agricultural (Irrigation)			
Along Qu'Appelle R. (Buffalo Pound & Upstream)	60,000	-	60,000
Along Qu'Appelle R. (Buffalo Pound to Craven)	48,000	-	48,000
Along Qu'Appelle R. (Craven to Manitoba boundary)	56,000	-	56,000
Along Orange Route**	111,000	-	111,000
Along Green Route** (Includes 140,000 dam^3 diversion to Souris Basin)	270,000	-	270,000
Red Route South of Craven** (Includes 140,000 dam^3 diversion to Souris Basin)	242,000	-	242,000

* Includes make-up for evaporation from lakes.
** Refer to Reference (2)

Note: 1 dam^3 = 1,000 cubic metres = 0.81 acre feet

TABLE 4

SUMMARY OF PROJECTED WATER DEMANDS

	1980	2030 Minimum	2030 Maximum
Regina			
Population	156,000	205,000	205,000
Average water consumption lcd[1]	545	640	820
Average daily consumption dam^3/day[2]	85(18.7)[3]	131(28.9)	168(45.7)
Ratio of peak day to average	2	2	2
Total annual consumption dam^3/year	31,230	48,000	61,500
Moose Jaw			
Population	34,000	50,000	50,000
Average water consumption lcd	580	640	820
Average daily consumption dam^3/day	20(5.44)	32(8.7)	41(11.1)
Ratio of peak day to average	2.6	2.6	2.6
Total annual consumption dam^3/year	7,000	11,700	15,000
Total Moose Jaw and Regina			
Annual consumption dam^3/year	38,230	59,700	76,500
Plus filtration losses	3,800	6,000	7,500
Grand total	42,030(25.4)	65,700(39.7)	84,000(50.7)

Notes:

1. lcd: litres per capita per day;
2. dam^3/day: cubic decameters per day;
3. figures in brackets are equivalent millions of gallons per day.

Over the course of a year, the Qu'Appelle River in its present condition can deliver 160,000[1] dam^3. After deducting losses in the river channel, evaporation from Buffalo Pound Lake, and a small amount of unavoidable spill past the gates in the Buffalo Pound dam, the net is 126,000 dam^3. According to table 3, the year 2030 annual demands can be summarized as follows:

Municipal supply for Regina and Moose Jaw	84,000 dam^3
Industrial	46,200
Recreation and wildlife	133,000
Agricultural (along the Qu'Appelle River, and along a proposed diversion route from Craven to the Souris River delivering 140,000 dam^3 to the Souris)	406,000

The present system can provide an adequate supply in Buffalo Pound Lake for the future needs of Regina and Moose Jaw. In a legal sense, only Regina and Moose Jaw now have a clear right to this water. They were authorized by the province in 1956 to divert up to 100,000 acre feet per year (123,000 dam^3 or 74.5 mgd) from the South Saskatchewan River. All other existing or proposed uses referred to above are licenced to use waters originating in the Qu'Appelle Basin, or are not licenced at all.

However, it would be rather cavalier to ignore the future demands for irrigation in the Qu'Appelle Valley flats, the public pressure for stabilization of levels in the lakes of the Qu'Appelle System, the growing needs of industry, and two other points not dealt with by the Phase I Committee. One is the certainty that Manitoba will expect delivery of its share of the Qu'Appelle River waters. The other is the possibility that Manitoba may request, and pay for delivery of a greater volume of water for use in the Brandon to Portage area.

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1 In 1981, the river was running near full capacity and the total flow past the grid road north of Keeler was 143,000 dam^3.

In summary, the present supply system can ensure a supply of water in Buffalo Pound Lake more than sufficient to serve year 2030 demands of Regina and Moose Jaw. However, the Upper Qu'Appelle River channel would require enlargement if other anticipated demands are to be served.

In order to convert the raw Buffalo Pound Lake water into drinking water, it is taken from the lake, pumped out of the valley to a filtration plant, treated, and sent by pipeline to Regina and Moose Jaw. The nature of the treatment required is described in the next chapter. However it should be noted here that expansion of the intake works (in Buffalo Pound Lake..... or elsewhere) will be required soon. The present intake has, by actual measurement, a maximum capacity of 34.8 mgd,[1] but because of several operational problems, it should not be operated much beyond 30 mgd. The current capacity of the filtration plant is nominally 30 mgd requiring input up to 33 mgd (plant losses of about 10%).

In the short term, the cities need:

a) An immediate increase of 2 mgd for Moose Jaw;

b) An additional 5½ mgd in the 1985-90 period to serve both cities;

c) A further increase of 7½ mgd in the 1990-95 period to serve both cities.

Consequently, a new intake capability must be built very soon at a cost of five to six million dollars (1982 prices). Therefore, an immediate decision is required as to where the intake will be, Buffalo Pound Lake, or elsewhere.

Other Supply Systems

Possible sources of supply, other than Buffalo Pound Lake, include groundwater, a pipeline or canal from Diefenbaker Lake or the Qu'Appelle River to the filtration plant, and a regional water scheme.

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1. in this report mgd means millions of imperial gallons per day.

Both cities were once completely reliant on groundwater. After connecting up with Buffalo Pound Lake, Moose Jaw abandoned its groundwater supplies. Regina has access to a much larger groundwater source and still uses well water for one-third of its requirements. However, largely for water quality reasons, Regina is likely to rely more heavily on surface water in the future.

A pipeline from Diefenbaker Lake to the filtration plant could supply the entire municipal needs of Regina and Moose Jaw and towns en route. The full capacity of the Qu'Appelle River, about 160,000 dam^3 per year would then be available to supply future demands for other uses. However, since the total of these projected uses (industrial, recreation and wildlife, agriculture) exceeds 160,000 dam^3 per year, the effect would be merely to postpone river channel improvements, not avoid them.

A canal from Lake Diefenbaker to the filtration plant would affect the overall supply situation in the same way as a pipeline, except for winter operation. If the canal could not be operated throughout the winter (still an unanswered question), it would be necessary to build a new reservoir near the filtration plant or continue to use the Buffalo Pound Lake intake for winter months.

A canal or pipeline scheme drawing from the Qu'Appelle River above Buffalo Pound Lake has been considered. It would have almost the same effect on the overall supply situation as the present system.

Various regional water schemes have been proposed for large canals that would convey water from Lake Diefenbaker to the Regina/Moose Jaw area and beyond. They would be designed to serve all uses en route including municipal, agriculture, industry, recreation and wildlife. Such a scheme would eliminate the need for eventual enlargement of the Qu'Appelle River channel.

Summary

If quantity were the only consideration, an adequate supply of water could be supplied toRegina and Moose Jaw:-

a) through the present supply system;

b) through a pipeline or canal direct from Lake Diefenbaker to the filtration plant;

c) through a pipeline or canal from the Qu'Appelle River to the filtration plant;

or d) through a canal that is part of a regional water scheme.

IV. THE WATER QUALITY PROBLEM

General

Water taken from a river or lake for municipal use is usually referred to as raw water. After treatment, it is called treated water. In the first part of this chapter, comments will be made on the quality of the raw water available to Regina and Moose Jaw. Later, comment will be made on the quality of the treated water.

Water vapour and clouds are the purest forms in which water occurs naturally. They receive some contamination from forest fires, dust storms, volcanic eruptions, industrial and automobile discharges to the atmosphere, and spraying operations for agriculture and forestry. When rain falls from the clouds, it contains, or washes from the air, some dissolved and particulate substances, but it is still relatively pure. After contacting vegetation and soil, the rain percolates through the ground (or runs off the surface) and carries more dissolved and particulate substances to the rivers. Evaporation from lakes and rivers, particularly in semi-arid areas, increases the concentrations of those substances. Generally speaking, the concentrations increase as a river flows downstream on its way to the salty ocean. A high rate of run-off and a short river produce better water than a low rate of run-off and a long river.

This natural process has been complicated by human activities. Sewage discharges from cities and effluent from industries change the water quality. Nutrients from sewage such as nitrogen and phosphorus stimulate the growth of weeds, algae, crustaceans and other aquatic life. Return flow from prairie irrigation projects contain higher concentrations of salts, particularly sodium. Marshes and lakes have high waterfowl concentrations during migration, contributing to nutrient loads, coliform bacteria, and sundry viruses. Industrial effluents may contain a wide variety of sub-

stances, some of them toxic or carcinogenic. When water is withdrawn from a river for any reason, the reduced volume remaining in the river provides less dilution for contaminants.

A complete description of processes affecting the quality of water in lakes and rivers would fill several books. These few remarks are sufficient to indicate that no natural water source is pure and that the degradation processes are complex. Further, a major impact of man's activities is the stimulation of growth of weeds, algae and other organisms in natural water bodies.

Water Quality Data are Approximate

Water quality is usually measured by taking water samples and analyzing them. The amount of various chemicals found in the water is usually expressed in milligrams (one-thousandth of a gram) per litre (or a very similar, though not identical, expression, parts per million). Whether the water is acidic or basic is indicated by the logarithmic pH number, 7 being neutral, lower numbers acidic, and higher numbers basic or alkaline. The presence of coliforms and nuisance organisms is usually expressed as a count of organisms per 100 millilitres. Most water samples are routinely analyzed for about forty ordinary chemicalsubstances. In addition, some are tested for coliforms and other bacteria, and any number of special substances that may be toxic if present in more than certain concentrations, for example polychlorinated biphenyls (PCB's), pesticide residues, etc.

Since each sample represents many hours of hard work in the field and the laboratory, water quality surveys are expensive. River and lake conditions such as flow, temperature and biological activity are always changing. Normally, it is too costly to keep up with all the changes so water quality is judged from samples taken monthly.....or even four times

a year. Therefore, even though water quality reports appear to contain precise numbers, the results they present are really quite approximate - and that should be kept in mind when reading this chapter.

The Quality of Raw Water Sources for Regina and Moose Jaw

The quality of four water sources must be considered: a) groundwater in Regina, b) Buffalo Pound Lake, c) the Qu'Appelle River before it enters Buffalo Pound Lake and d) Lake Diefenbaker.

"The Regina Aquifer system (2) provides water of acceptable quality except for iron, manganese, total hardness, and total dissolved solids which exceed Provincial Objectives and, in some cases, manyfold". Since the aquifer is relatively shallow, there is also a risk of contamination from human activity on the land surface. The present well system is capable of meeting about one-third of Regina's requirements. However, because of the known and potential quality problems, serious consideration is being given to the phasing out of groundwater for municipal use. The aquifer would then be available for industrial use.

Buffalo Pound Lake is about 30 KM long, almost 1 KM wide and has an average depth of 3 M. The outlet of the lake (the Qu'Appelle River) is just upstream from the confluence with the Moose Jaw River. Before 1938 (when the first dam was built on Buffalo Pound Lake), the spring floodwaters from Moose Jaw Creek often exceeded the capacity of the Qu'Appelle River and caused reverse flow into Buffalo Pound Lake. After the dam was built, this situation continued but to a lesser extent. The floodwaters contained high sediment loads that settled out in the lake. The sediments contained considerable phosphorus and other nutrients contributed over the years from the rich prairie soils, wildlife, waterfowl, and the Moose Jaw sewage disposal system. Now, Moose Jaw can contain its effluent for a few weeks dur-

ing flood periods but the bed of Buffalo Pound Lake is already covered with sediments rich in phosphorus.

Winds and currents keep the lake waters well mixed and ensure widespread distribution of dissolved material from the lake bed. The result is a water body that is almost ideal for the growth of many forms of algae, and other organisms. There are many kinds, and when conditions favour the growth of one kind over the others, there is said to be a "bloom" of that species. Algal blooms are frequent every summer in Buffalo Pound Lake. One characteristic of a bloom is that the supply of a nutrient needed for the blooming species may be quickly exhausted. Then most of that species dies suddenly and a new one takes over. The sudden collapse of a bloom leaves many tons of dead and decaying organic material in the lake. It can cause a dip in oxygen levels and the release of toxic substances, resulting in fish kills or deaths of animals that drink water at badly polluted locations.

Algae accumulates along the shoreline but usually there is less algae near the intake structure which is several hundred feet from shore. When blooms occur in late summer, concentrations are high throughout the lake, and the water delivered to the filtration plant presents severe problems to the present treatment systems.

Aside from the algae problem which complicates the treatment process, the quality of Buffalo Pound Lake is acceptable as a raw water source and it has been improved by the importation of better water from Lake Diefenbaker. The natural run-off to the Upper Qu'Appelle River contains minerals from springs in the Tugaske-Central Butte area. It also contains significant phosphorus loadings from run-off from fertile prairie soils, marshes used by waterfowl (e.g. Eyebrow Lake) and from livestock feeding

areas. At the intake, the total dissolved solids concentration varies with the season. It is highest just before spring break-up, and lowest immediately afterward when the ice melts. It also varies from year to year. At the risk of oversimplification, an average TDS of 350 parts per million is suggested for comparison with Lake Diefenbaker which is about 250. On the average, phosphorus is only a little higher than in Lake Diefenbaker, although there can be sudden peaks. Nitrogen is higher in Buffalo Pound Lake, though not alarmingly so. One marked differnce is the higher count of fecal and total coliforms found in Buffalo Pound Lake.

The quality of the water in the Qu'Appelle River depends upon how much flow is being released from Lake Diefenbaker. In October, 1982, a consultant (4) reviewed data collected over two years and reported to PFRA as follows:

"The high flows sustained through the summer of 1981 tended to stabilize and minimize downstream deterioration. Selected observations for the site north of Marquis include:

- algae populations contained species often associated with water treatment problems but the low counts would permit effective treatment with conventional processes.
- the site is susceptible to bacteriological concerns, primarily from animals or birds.
- colour, turbidity, and suspended solids were substantially increased during higher flow regimes from channel or bank erosion. Fine silts and clays make up the bulk of the large loadings.
- if adequate sustained flows were maintained (from Lake Diefenbaker) and appropriate withdrawal and pumping facilities constructed, the water would be suitable for a municipal supply. Primary concerns would be the high turbidity/suspended solids levels, the potential for bacterial problems, and possible problems with aquatic biota."

In addition, the possibility of future irrigation development south of the Qu'Appelle River must be kept in mind. In a recent study, PFRA identified 140,000 acres of irrigable land from which return flows would reach the Upper Qu'Appelle. Assuming a return flow of four inches over a four-

month summer period, there would be a discharge of 5.5 m^3/sec to the Upper Qu'Appelle River. The concentration of dissolved solids in this water would be higher than in Lake Diefenbaker. Since 5.5 m^3/sec is half the channel capacity of the Upper Qu'Appelle River, return flows would be the major flow component and the TDS of the river would be increased substantially.

The quality of the water in Lake Diefenbaker has been described by M.R.2 (4) as follows:

- "the dominant algae diatoms and blue greens and species were identified that may be troublesome in water treatment. However, densities were relatively low and should not create problems with conventional treatment.
- based on the available information, the lake would provide suitable raw water of moderate hardness for municipal supplies.
- with its good and reasonable consistent quality, the treatment of the lake water would be relatively straightforward and inexpensive."

Since Lake Diefenbaker will continue to be the source (by pipeline, or indirectly via the Qu'Appelle and Buffalo Pound Lake) of water for Regina and Moose Jaw, it is important to know or to judge what the future quality of the lake waters will be. The quality is good now. But there are urban centres, totalling 740,000 people, and their industries in the Alberta portion of the basin, and another 20,000 in Saskatchewan. With or without growth, the total nutrient loading to the lake will be large. M.R.2 puts it this way:

> " a preliminary examination of phosphorus loading in terms of trophic status suggests a potential concern that warrants more detailed review and assessment"
>
> - and -
>
> "the lake is relatively young and should maintain satisfactory overall water quality well into the future but it would be timely to undertake work to better define potential impacts from Alberta since that Province's contributions will play a major role in the future of the lake".

A review of data extending over fifteen years (5)(6)(4) indicates no significant trend, up or down, in water quality in Lake Diefenbaker or in the South Saskatchewan River at the Alberta/Saskatchewan Boundary.

One more observation may be made. The City of Medicine Hat uses powdered activated carbon to combat taste and odour problems caused by algae decomposition in the South Saskatchewan River. The algae growth is stimulated primarily by nutrients in sewage effluents discharged to the river system upstream from Medicine Hat. By the time the river reaches the Saskatchewan border it meets the water quality objectives of the Prairie Provinces Water Board. As long as Alberta continues to upgrade its sewage treatment facilities, that will be the case with respect to nutrients.

At the risk of oversimplification, a table has been prepared to compare the four water sources. The assessment for Buffalo Pound Lake and the Qu'Appelle River assumes that releases from Lake Diefenbaker are sufficient to provide an adequate supply to Regina and Moose Jaw.

RAW WATER SOURCE

	Regina Groundwater	Buffalo Pound Lake	Qu'Appelle River north of Marquis	Lake Diefenbaker
Total dissolved solids or selected chemical constituents	Often exceed drinking water objectives	T.D.S. 50% higher than Lake Diefenbaker	T.D.S. similar to Lake Diefenbaker higher turbidity and phosphate	In the 250 PPM range for T.D.S. All other chemical constituents within drinking water objectives
Coliforms and other bacteria	Very low to nil counts	Usually low but subject to sudden though short-lived increases.	Has occasional peaks higher than Buffalo Pound Lake due to non-human sources.	Very low counts
Hardness	High	Moderate	Moderate	Moderate
Algae and related substances	Very low or nil	Extreme	Moderate	Low
Supply	Insufficient and does not serve Moose Jaw	Adequate	Adequate	Adequate
Overall Rating	Insufficient supply	Third Best	Second Best	Best

Treatment Processes

The present filtration plant at Buffalo Pound Lake has a conventional treatment process consisting of prechlorination, coagulation, settling, pH adjustment, and filtration.

Prechlorination breaks down or kills algae, removes their surface slimes and makes them easier to remove in subsequent treatment stages. Initial reaction of chlorine with algae and other organic substances produces trihalomethanes (THM). During a pilot plant test in August 1980, prechlorination was producing THM's at 111 micrograms per litre (100 is the plant objective and the Saskatchewan standard is 350) after settlement.

Settlement is achieved by adding alum and other flocculants and allowing the floc to settle. After settlement, a large part of the organic load has been removed. However after pH adjustment, the remaining organics and THM's enter the filtration process. If a lot of organic material survives prechlorination, the sand filters will clog more rapidly and require more frequent backwashing. THM's pass through sand filtration without much change because they are in solution. Any algae, dead or alive, that remain after filtration will cause taste and odour in the finished water. Also, any toxins released by the algae decay process will be in the finished water. Algal toxins, and THM's occur in the finished water from the present plant. The main question is whether or not the concentrations are high enough to be hazardous to health.

The December 1980 report by CH2M Hill Canada Ltd., describes the causes of taste and odour as follows:

"Excessively high algae concentrations make it difficult to remove all of the algae cells in the treatment process. Operation of the water treatment plant during peak demand periods results in algae cells being present in the finished water..... In addition, during periods of crustacean "blooms", it is extremely difficult to remove, or even kill, all crustaceans in the clarification treatment step. Most of the live

crustaceans find their way to the filters. Most of them are removed in the process but a turbidity breakthrough can pass crustaceans, pieces of crustaceans, or crustacean eggs into the finished water. These may contribute to the taste and odour problems in the finished water."

In December 1980, a number of questions regarding the Buffalo Pound Water System were put to an Advisory Medical Panel.

The Panel concluded that it was virtually impossible for a lethal dosage of algal toxin to be carried through the treatment plant and into the distribution system. They also said that algae or algal toxins would not contribute significantly to carcinogenic substances in the water supply. They observed further that if carbon adsorption treatment were added, it would reduce the level of toxins, reduce taste and odour, and ensure that potential carcinogens are restricted to acceptable levels. The latter observation concerned reduction of the THM levels.

One must conclude that the water produced by the filtration plant is medically safe, though at times unpalatable.

The addition of granular activated carbon contactors after the filtration process will remove by adsorption a large portion of the THM produced by prechlorination. In the pilot plant tests in 1980, the contactors reduced THM levels from over 100 micrograms per litre to 4 or less. It would also adsorb most of the organic compounds produced by the decay of algae earlier in the system. Algae cells, crustaceans and bacteria that pass through the sand filters would not be adsorbed, but might be caught in the carbon requiring frequent backwashing. Carbon filtration would reduce the TON to acceptable levels and give an extra margin of safety with respect to THM's and algal toxins.

Another addition to the treatment process that could be considered is a detention pond between the intake and the filtration plant. The pond would be sized to provide five to seven days detention. It permits the application of chemicals such as copper sulphate to kill or settle most of the algae and other organisms before chlorination and clarification. With

less organic material reaching the chlorination stage, the production of THM's is much lower, and the probability of organisms and toxins persisting through to the finished water is greatly reduced.

Many centres in North America that must deal with algae-ridden raw water use both detention ponds and carbon contactors in the treatment process.

In the balance of this report, several alternatives are examined for improving the taste and odour of Regina-Moose Jaw water. Although the emphasis is on taste and odour, any reduction that can be achieved in the concentrations of THM's and algal toxins is to be applauded. There is still some uncertainty as to the long-term effect of ingesting these substances.

It is interesting to note that sixty-four communities in Saskatchewan (7) recognize a taste and odour problem in their municipal water supplies. The water is treated (carbon is the dominant method) by forty-three communities to remove the taste and odour. In the remaining twenty-one communities, no taste and odour treatment has been instituted. The forty-three communities have a total population of 52,412 and the twenty-one communities have 100,669.

V. ALTERNATIVE SOLUTIONS TO THE WATER QUALITY PROBLEM

General

There are two basic approaches to the solution of the water quality problem, one is to obtain raw water of better quality, and the other is to increase the amount of water treatment. Six of the eight alternative solutions described in this chapter are in the first category and two are in the second. The notes on each alternative follow an identical format, to aid in the comparison of one alternative with another. The highlights of this chapter are summarized in table 5.

- description;
- impact on water quality;
- other impacts;
- adaptability to future needs and other uses;
- cost;
- time required for implementation;
- other observations.

The information in this chapter comes from several sources. In some cases, the notes are derived from lengthy investigations; in other cases, the background is not as complete. Consequently, such things as "impact on water quality" or "cost" will be more accurate in some cases than in others. Any differences are described in the text, and appear too on table 5. Final design has not been done for any of the alternatives therefore, the cost estimates must be considered "preliminary".

In all cases, the costs do not include expenditures necessary to expand existing water treatment delivery and distribution facilities to serve the growing population. Since they are the same in all cases, inclusion of such expenditures would not aid the comparison of alternatives. In alteratives 4 and 7, the costs of specific additions to the treatment process are included, but those costs are related to taste and odour control only.

Two terms used in the cost estimates should be defined as used in this report:-

Annualized cost is the amount required as a payment each year over a fifty-year period to repay borrowed capital, operating costs, maintenance costs, and energy costs.

Present worth is a lump sum in hand that is equivalent to a future payment or expenditure. Using a discount rate of 5% (corresponding approximately to an interest rate of 14% and inflation rate of 9%), a lump sum in hand of $100 is equal to $95 paid one year from now, or to $61.39 paid ten years from now.

At the conclusion of each cost presentation, the "annualized cost" is given. That figure permits a quick monetary comparison between alternatives. In computing the annualized cost, it was assumed that a discount rate of 5% would be applicable to future expenditures, and that funds could be borrowed at an interest rate of 12%. It is emphasized that the analysis is not rigourous and the estimates would change substantially after detailed design and careful review of inflation and discount rates.

All alternatives were sized to serve (in stages where appropriate) the Level II demands in the year 2030 as shown in Table 3.

It was assumed, for all alternatives, that the cities would construct works, as requested by Saskatchwan Environment, to treat the backwash from the filtration plant. The backwash contains organic material that should not be returned untreated to Buffalo Pound Lake. By the year 2030, if 10% of the incoming water is used for backwashing and other plant usage, the waste discharge will reach an average year round flow of 4 mgd (7.4 cubic feet per second) with higher values in summer.

The cities of Regina and Moose Jaw were authorized in 1956 (before the Gardiner Dam was built) to take 100,000 acre feet per year from the South Saskatchewan River. That amount of water would generate about 250 KWH of electrical energy (13) at the Coteau Creek and Squaw Rapids hydro plants.

Because the authorization for the cities was given before the authorization for the hydro plants, no value appears in the cost estimate for the energy foregone. Even in those cases where more than 100,000 acre feet would be diverted in one year, (for example, alternative 3) the value of energy foregone was not estimated.

1) Pipeline to Lake Diefenbaker:

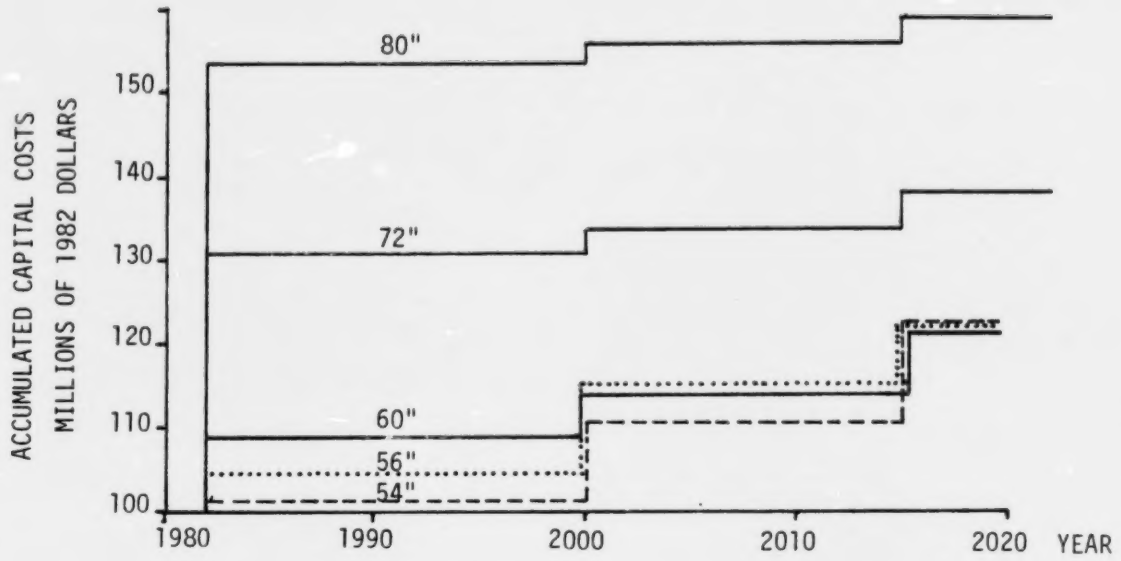
Description: This alternative consists of an intake in Lake Diefenbaker, a pumping plant nearby, and an 87 km pipeline to a six-day detention pond at the filtration plant (10). No change would be made to the treatment process and additions to the plant capacity would be made from time to time to meet the growing demand. The pipeline diameter has a major impact on costs, so some preliminary discussion of this matter has been included.

Cost estimates for various sizes of pipelines were prepared (10). In each case it was assumed that, by the year 2030, the scheme must be capable of delivering the six-day peak level II demand (table 3). Large pipeline diameters have high initial costs, but low operating costs and energy charges. Small pipeline diameters have lower initial costs, but additions to meet growing demands yield higher capital costs eventually. For the small pipeline diameters, operating and pumping costs were much higher. Two graphs have been prepared to illustrate how these costs vary with pipeline diameter.

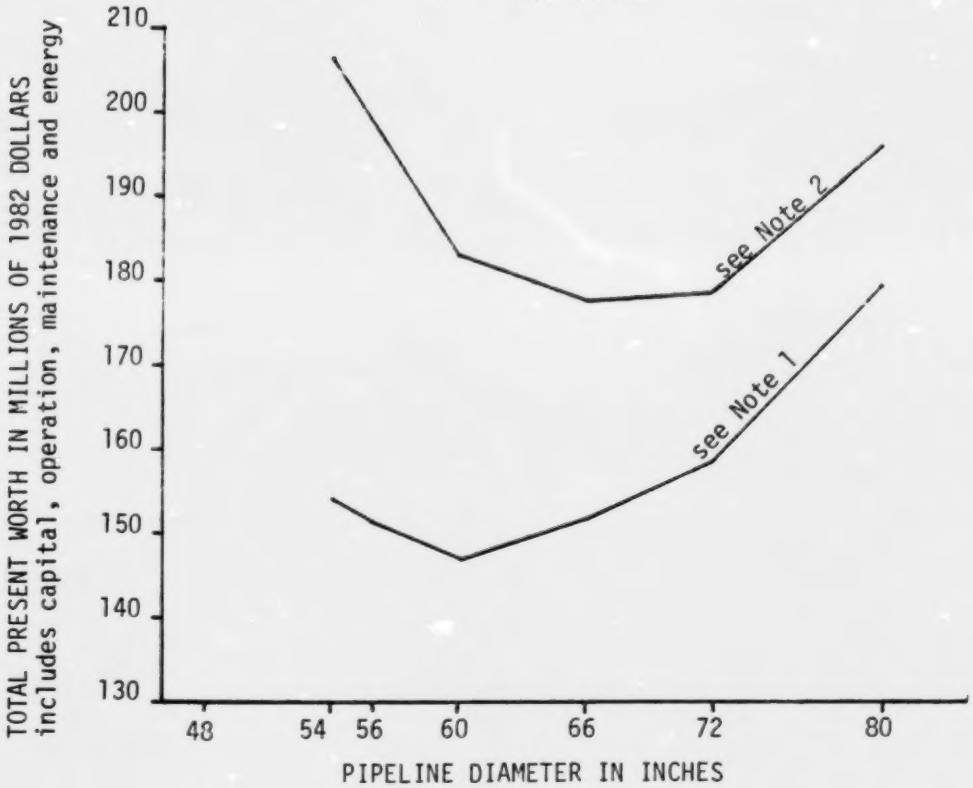
It is apparent from the graphs that the selection of a small pipeline diameter would save on initial capital expenditure, but to have the lowest annualized cost, a 60" diameter should be selected. These curves were based on recent work (10) and include the assumption that future energy costs will stay the same in relation to other goods and services. If energy costs should rise more rapidly, larger pipeline diameters would be favoured.

Figure 4

EFFECT OF PIPELINE DIAMETER
ON CAPITAL COSTS

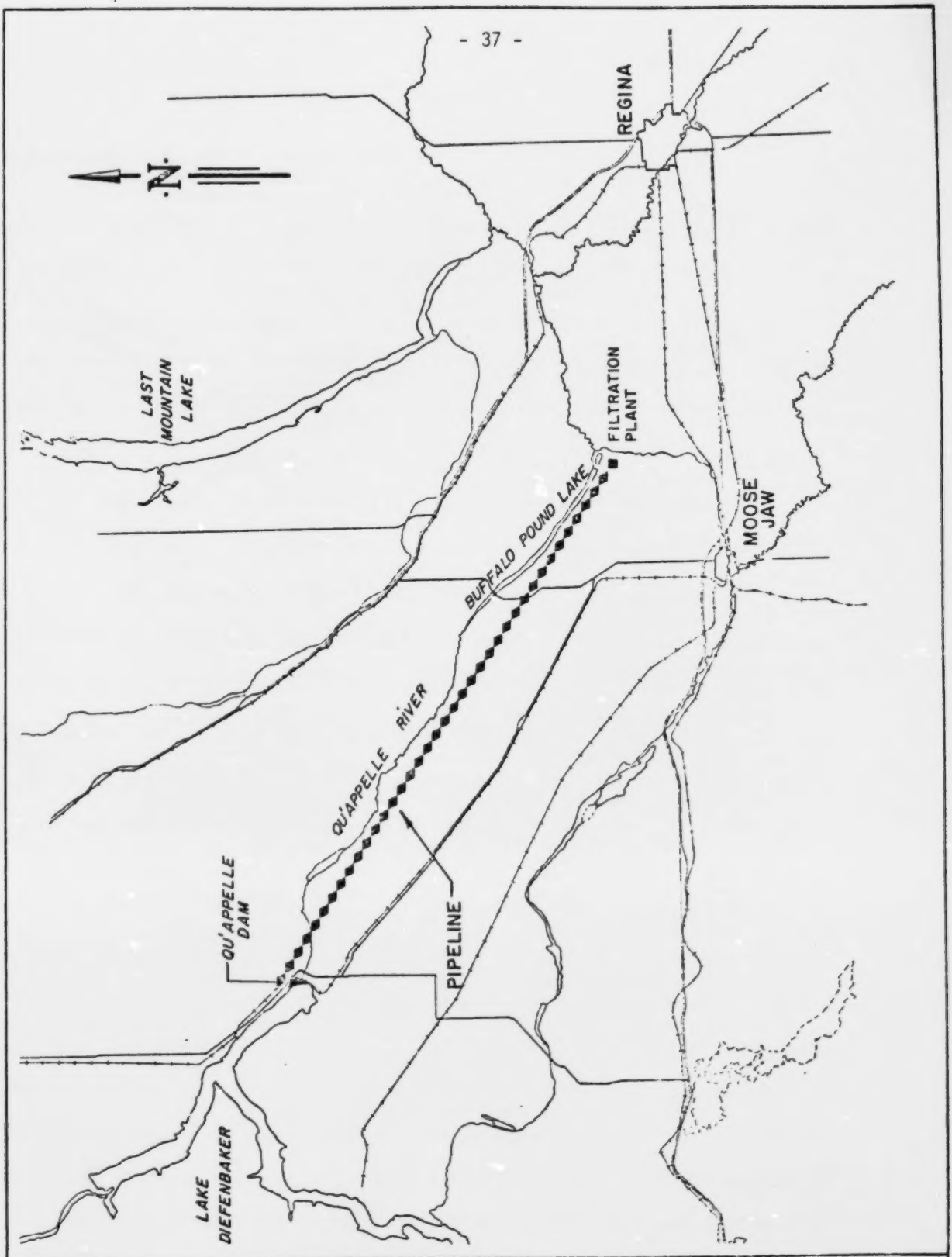


EFFECT OF PIPELINE DIAMETER
ON PRESENT WORTH



Note 1: Escalation in energy rates same as general inflation rate

Note 2: Escalation in energy rates 5% more than general inflation rate.



DESIGNED DRAWN CHECKED	SUBMITTED DATE APPROVED DATE CHIEF ENGINEER PFRA	Government of Canada / Gouvernement du Canada Regional Economic Expansion / Expansion Économique Régionale PRAIRIE FARM REHABILITATION ADMINISTRATION ENGINEERING SERVICE	ALTERNATIVE 1 PIPELINE TO LAKE DIEFENBAKER SCALE / DATE / SHEET OF

Figure 1

It should be noted that the 60" size is best if the level II demands (2) must be met in the year 2030. If the actual demands are smaller, a smaller diameter pipeline would have a lower present worth and annualized cost.

Impact on Water Quality: In Chapter III a comparison was made between the quality of water in Lake Diefenbaker and other sources. The quality is best in the lake.

Using raw water from Lake Diefenbaker, it is likely that the effective capacity of the sand filters at the filtration plant would be increased. Because the water would contain less organic material, less would be deposited in the filters and downtime for backwashing would be reduced. Existing processes at the plant would have no difficulty in producing a first-class finished water with a very low TON. Pre-treatment would take place in the detention pond. If chemicals other than chlorine could be used in the detention pond, most of the organic material would be removed before chlorination. The result would be very low concentrations of trihalomethanes.

From a water quality point of view, with no consideration of cost, a pipeline from Lake Diefenbaker would provide the best solution.

Other Impacts: A decision to build a pipeline would segregate the needs of Moose Jaw and Regina from all other water needs in the Qu'Appelle system. The importation of water to the Qu'Appelle River would no longer be needed to provide municipal supply for the cities. The importation facilities would be used for, and justified by, other uses such as recreation, wildlife, agriculture and industry. The cities would no longer rely on operations conducted partly for other purposes.

It is assumed that the pipeline would be designed and built to

accomodate requirements of the Department of Environment and that there would be no unforseen deleterious side effects.

It is interesting to note that the pumping horsepower requi... in the year 2030 is quite large. It has been estimated as follows:-

Pipe diameter	Horsepower required to drive pumps in the year 2030	% of installed capaci... at the Coteau Creek generation station
48"	120,000 (extrapolated)	48
56"	78,000 (10)	31
60"	49,000 (10)	20
72"	24,000 (10)	10

In addition, energy is needed to operate the filtration plant and del... the water to Regina and Moose Jaw.

Adaptability to Future Needs and Other Uses: As explained in the pre... section, a pipeline decision would separate Regina and Moose Jaw needs ... all other uses.

A pipeline system adapts to growth in municipal demand by i... - ing the pressure to deliver more water, or by adding parallel lines. ... a certain growth forecast has been accepted, the selection of the bes... bination of pipe diameter and pumping power can be made on economic gr... Other factors will no doubt be considered, but as long as all the cost f... rs are available, decisions can be made with eyes open.

The availability of a cheaper source of raw water from a regi... l water scheme would require some hard decisions as to the future of the ... - line system.

Cost: The cost of two pipeline options would be as follows:-

	56"	60"
Initial capital costs (1982 dollars)		
. pipeline	$77.5 millions	$84.0 millions
. intake and pumps	22.8	21.0
. detention pond, pumps, etc.	7.9	7.9
Present worth of future capital expenditures		
. additional pumps	6.1	3.8
Present worth of operation, maintenance and energy	37.0	30.3
Total present worth	151.3	147.1
Annualized cost	18.2	17.7

Note: Cost estimate is based on reference (10) with 3.6 million added to convert buffer storage into a six-day detention pond.

Time Required For Implementation: Design, construction, and commissioning of the intake works would require two years. Additional time would be required if the manufacture of suitable pumps causes delay, or if difficult foundation conditions are encountered at the intake. Two years would be sufficient for the construction of the pipeline.

Other Observations: The public now perceives that this alternative will produce high quality water. However, it is not known (because no one has previously worked it out) how much each householder must pay towards the construction and operation of this system. There will no doubt be great pressure from Regina/Moose Jaw citizens for grants and concessions to reduce their share. There could be reluctance in the rest of the province to approve such grants and concessions. Without them, public support for this project would be weakened. No one really knows the monthly amount that the Regina/Moose Jaw people are prepared to pay for good water. Until that is known, the gap between their willingness (or ability) to pay and the true costs cannot be identified.

2) Canal to Lake Diefenbaker

Description: This alternative is similar to alternative 1(pipeline) except that the water would be conveyed by open canal from Lake Diefenbaker to the detention pond at the filtration plant (10). The intake works in Lake Diefenbaker would discharge through a short pipeline into a 96 km canal that would flow by gravity to the filtration plant. The canal would be located so as to avoid picking up local run-off, and, where deemed necessary, it would be fenced to prevent direct contamination from livestock.

It is possible that the canal could be designed so as to operate effectively all winter. However, it may not be possible to re-establish the flow after an emergency shut-down of several days in mid-winter. Consequently, it is assumed that the present intake works on Buffalo Pound Lake would be retained, maintained, and used as a back-up source of raw water in winter. The present capacity of the intake and pumps is just sufficient to meet the year 2030 winter demand.

Some comment is made here on the Buffalo Pound Lake management problem even though it applies in part to all alternatives. From a flood control viewpoint, a low lake level is desirable in spring so the lake can be used to moderate flood peaks. But when used for municipal use, the level must be kept relatively high all winter. Also, if levels are too low in winter, there could be (and has been) large fish kills when decaying organics deplete the oxygen supply under the ice. A scheme that relies on Buffalo Pound Lake for winter municipal supply will complicate the management of the lake levels. But, even if the lake were not used for municipal supply, the management problem is only moderated, not removed.

Impact on Water Quality: Factual data are scarce on water quality changes in long canals. During its recent investigations, PFRA discussed the question with water quality and irrigation people in Alberta and Denver, Colorado.

The concensus was that, if a long canal is protected from contamination from local run-off and livestock, the quality of water will change very little throughout its length. It can be expected that the canal will experience some increase in salts leached from the bed and banks, however it is likely to be insignificant. Growth of algae and other organisms in a flowing canal have not been a problem elsewhere. Even if there is some turbidity picked up in the canal, it would be easily removed in the detention pond or in the clarifiers.

The quality of the finished water should be very good -- about the same as for alternative 1 ... except for winter periods when the Buffalo Pound intake would be operating. During those periods, taste and odour should not be a problem but there could be other effects. The quality of the water in Buffalo Pound Lake depends upon the amount of inflow from Lake Diefenbaker. Winter releases from Lake Diefenbaker to the Qu'Appelle River may be discontinued when the main supply to Regina and Moose Jaw arrives directly by canal. Concentrations of all minerals can be expected to increase as the amount of inflow decreases. The higher mineral content, (perhaps 50% increase in total dissolved solids) would appear in the finished water.

Other Impacts: It would be possible to use the canal as a source of raw water for any communities or industries located close enough to it. A pipeline could be located so as to serve intermediate communities but a gravity canal location is dictated by the contour of the land. The location presently indicated for this canal is within three miles of four communities - Riverhurst, Central Butte, Tugaske and Pense.

During the summer, the water needs of Regina and Moose Jaw would be segregated from other uses in the Qu'Appelle Basin such as recreation, wildlife, and agriculture. The supply of water from Lake Diefenbaker

to the Qu'Appelle would no longer be justified in part by Regina-Moose Jaw needs - except for winter supply. Releases from Lake Diefenbaker to serve those other needs would maintain an acceptable quality of water in Buffalo Pound Lake for winter supply to Regina and Moose Jaw.

It is assumed that the canal would be built to accomodate requirements of the Department of Environment and that there would be no unforseen deleterious effects. The number of potential severance problems will depend upon the skill of the persons negotiating the right-of-way.

The amount of energy needed to drive water through a canal system is less than for a pipeline. It is estimated that by the year 2030, one-fifth of 49,000 H.P. will be needed to lift water from Lake Diefenbaker, and place it into the canal to serve municipal uses. That can be compared with the 49,000 H.P. needed for a 60" pipeline for municipal use only, or 9,000 H.P. to draw from Buffalo Pound Lake through the present system.

Adaptability to Future Needs and Other Uses: This alternative envisages a supply canal designed to serve only Moose Jaw and Regina and communities near the canal. As described for alternative 8, there are large tracts of irrigable land commanded by the canal route. The supply canal could be enlarged at some later date to serve irrigation needs. However if irrigation were a serious consideration, it would probably be less costly to construct an appropriate size of canal in the first instance---in which case the initial choice should be made between alternatives 3 and 2, rather than considering a future enlargement of the alternative 2 canal.

Cost: It is felt that this canal could not be reserved for the exclusive use of the two cities. In dry years particularly, there would be an almost irresistable demand for irrigation water by those farming near the canal. The result would probably be a staged development of alternative 3. Therefore no cost estimate has been prepared. The annualized cost given in table 5 is taken from reference (10).

Time Required for Implementation: Two years would be required for design, construction and commissioning of this alternative.

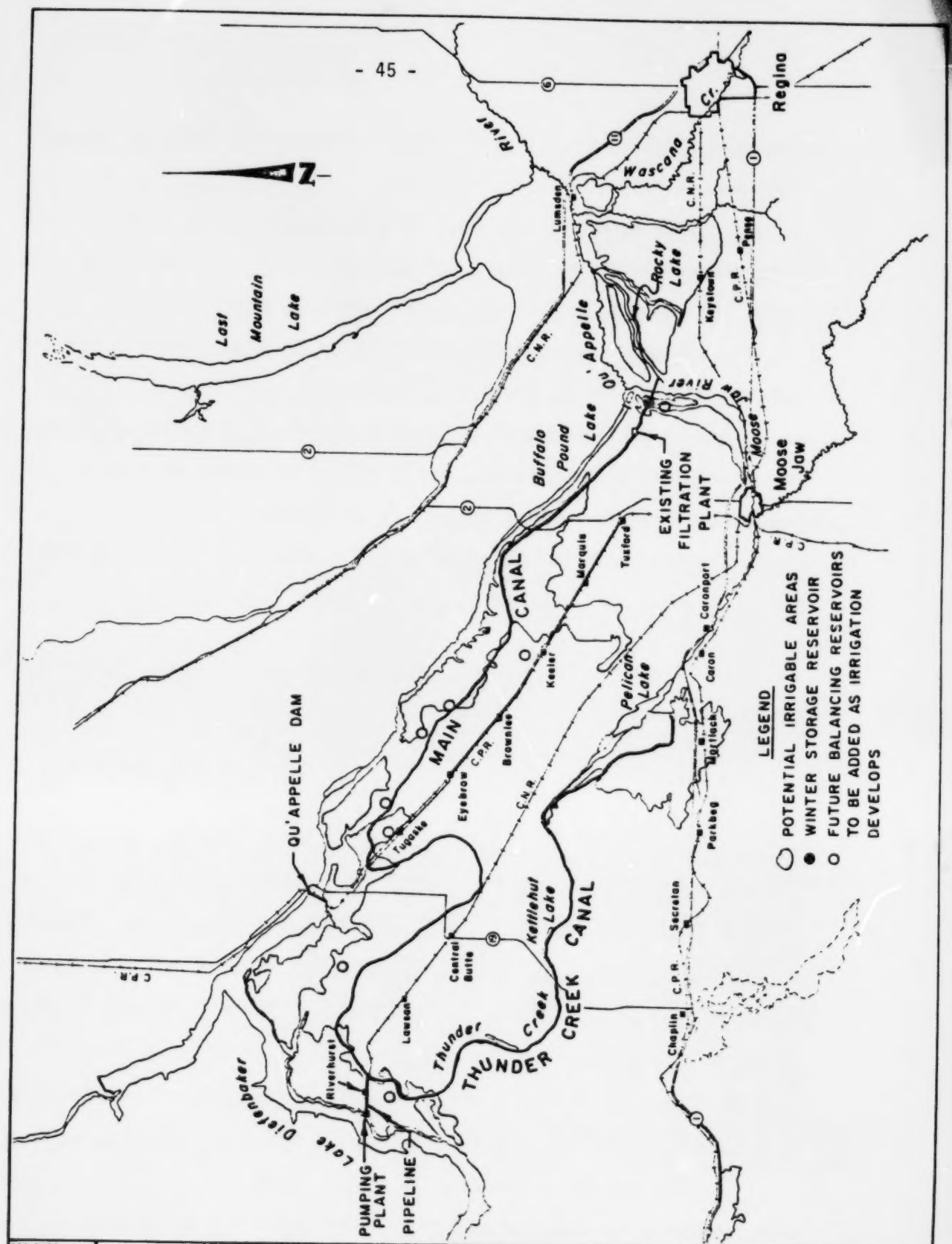
Other Observations: Over the years, many "experts" have expressed conflicting opinions regarding Buffalo Pound Lake and alternative water sources. One result is a healthy skepticism on the public's part regarding any "expert" or government pronouncement. Consequently the public may not accept that the quality of water delivered by an open canal would be as good as pipeline water. There would likely be a "wait and see" attitude that would generate rumblings for a few years. In particular, the quality of water during the winter would be observed carefully because raw water would be drawn from Buffalo Pound Lake for some periods. Frequent reports to the public on the quality of the raw and finished water would probably head-off popular criticism.

3) Regional Water Scheme:

Description: A pumping plant at Lake Diefenbaker, near Riverhurst, would lift water to a canal which would have two branches. The main canal would follow the uplands south of the Qu'Appelle Valley from Bridgeford to Tuxford. From there it would flow past the filtration plant to a large balancing reservoir (29,000 dam^3) about 5 km southeast of the filtration plant. After crossing Moose Jaw River by pipeline, the canal would continue generally eastward and south. Another pumplift southeast of Pense would feed a gravity canal that could discharge into the Souris River.

A secondary canal would flow south of Riverhurst into Thunder Creek.

Along the main canal 140,000 acres of potential irrigation have been identified between Riverhurst and Tuxford. Another 57,000 acres could be commanded in the Stoney Beach area. Along the secondary canal, 37,000



DESIGNED	SUBMITTED	Government of Canada / Gouvernement du Canada	ALTERNATIVE 3 - REGIONAL WATER SCHEME
DRAWN	DATE	Regional Economic Expansion / Expansion Économique Régionale	
CHECKED	APPROVED	PRAIRIE FARM REHABILITATION ADMINISTRATION ENGINEERING SERVICE	SCALE / DATE / SHEET OF
	DATE CHIEF ENGINEER PFRA		

Figure 2

acres of irrigable land have been identified north of Mortlach and another 7,000 acres scattered along Thunder Creek.

Many potential waterfowl breeding and staging areas could be developed along both the main and secondary canal systems. In particular, the levels of Kettlehut, Pelican, and Eyebrow Lakes could be stabilized.

Future industrial development in the Riverhurst, Moose Jaw-Regina, Weyburn, Estevan corridor would be a potential customer.

The canal system would probably operate in the summer only, making it necessary for year-round users to draw from storage in winter. Some of the dimensions of the project are as follows (10):

- Total lift from Lake Diefenbaker to the canal — 190 feet
- Total length of main canal to storage reservoir — 99 miles
- Horsepower required at intake for year 2030 development of all uses — 49,000 H.P.

	Main Canal		Thunder Creek
	at beginning	at filtration plant	Canal
. capacity	970 cfs	320 cfs	350 cfs
. bed width	18 ft.	13 ft.	
. width at water line	72 ft.	49 ft.	
. top width	116 ft.	67 ft.	

Impact on Water Quality: This alternative would deliver Lake Diefenbaker water to the filtration plant in summer. In winter, municipal water could be drawn from the balancing reservoir about 5 km southeast of the filtration plant. The quality of the water delivered to the plant in summer would be almost as good as the water in Lake Diefenbaker. There may be some turbidity picked up through canal erosion, but it would present no serious treatment problem. There may also be a slight increase in some salts due to leaching from the canal banks but experience in Alberta indicates that it is negligible.

The quality of the water in winter, taken from the balancing reservoir, should be far superior to Buffalo Pound water, but not as good as Lake Diefenbaker water. The water quality of the winter reservoir cannot be pre-

dicted precisely but it is not likely that the change from summer to winter would be noticed.

The canal location and design prevents most of the natural run-off from entering the canal, thereby avoiding serious bacteriological contamination.

Adaptability to Future Needs and Other Uses: The purpose of this project is to serve "future needs and other uses". To the extent that future needs are known or can be predicted, they can be provided for in the project layout and design. Consequently, a regional water scheme must rank first under this heading.

Other Impacts: This alternative has many more impacts than any of the others. The good impacts are found in the wide range of uses that would be served. Some of the other impacts are as follows:-

- A long system of canals must be very carefully planned and land ownership adjusted so as to minimize severance problems.
- Return flows from irrigation projects will improve quality of receiving streams in dry periods, but may increase the TDS over natural values during ordinary and high flows.
- All proposed uses would be served from the canal system without requiring releases into the Qu'Appelle River. The reduction in releases to the Qu'Appelle is desirable in wet years. In dry years, special releases from Lake Diefenbaker will still be required to meet wildlife and recreational needs along the Qu'Appelle.

Cost: The cost estimate shows the overall estimated cost of the project for all purposes. Since only 20%[1] of the water would be taken by Regina and Moose Jaw, one could argue that the charge to municipal water supply would be 20% of the total.

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1. estimated percentage of the total diversion that would be delivered to the filtration plant.

Initial capital costs (millions of 1982 dollars)(10)		
. canals, syphons, right-of-way, etc.		74.6
. Thunder Creek canal		16.7
. extension of canal to Rocky Lake		5.4
. main pumping plant and intake		64.4
. other pumping facilities		12.1
. internal reservoirs		39.1
. upgrade detention pond		3.6
	Total	215.9
Present worth of future capital expenditures		
. additions to pumping facilities		26.7
Present worth of operation, maintenance, and energy		
. operation and maintenance		58.6
. energy		57.0
Total present worth		358
Annualized cost		43.1
20% of annualized cost		8.6

Time Required to Implement: First senior and municipal governments must agree in principle to proceed, then the overall project would take five years for planning, design, and construction.

Other Observations: This scheme is likely to generate strong support in the area to be benefitted and adverse reaction from areas downstream along the South Saskatchewan River. In particular, those people living in the area that would be commanded by the "west side" canal from Lake Diefenbaker would feel that their development would be precluded, or at least delayed, by the regional scheme.

Some persons have suggested that federal interest may be high in this project because of its role in regional development. If that interest were high enough to fund its construction, the province would realize a large new development potential at very reasonable cost.

4) Present Supply System with Activated Carbon Contactors Added:

Description: In this alternative, granular activated carbon contactors are added to the present water treatment system. Activated carbon can adsorb a

variety of dissolved material and small particles, including chemicals produced by the decay or organic substances, thereby removing causes of taste and odour. The process was described in the previous chapter. The intake structure would continue to be located in Buffalo Pound Lake, and expanded as required to serve the growing water demand. From 1982 to 2030, the power required at the intake would increase from 2,500 H.P. to 9,000 H.P. Water would be released from Lake Diefenbaker to maintain the levels of Buffalo Pound Lake. The releases would be about half of those for alternative 8 to meet present demands, but about equal to alternative 8 releases by the year 2030.

The filtration plant would be expanded by the addition of concrete cells to house the carbon beds. After passing through the existing sand filters, the water would flow through the carbon beds to a clearwell. Chlorine addition for disinfection will be required following adsorption (because chlorine is removed by the adsorption process). The carbon beds would be arranged in groups of four beds with a pump to provide for staged construction and to allow maintenance on the pumps without a complete shutdown.

Material trapped in the carbon beds is removed by frequent backwashing. However when the adsorptive capacity of the charcoal is used up, the beds are no longer effective. Then the carbon must be regenerated by driving off the adsorbed material. This alternative includes a multiple-hearth furnace and ancilliary equipment that would have the capacity of regenerating all the carbon in the beds within a six-month period. The carbon regeneration process produces a waste that can be handled by proposed facilities for treating filter backwash.

The concrete cells to house the carbon beds, are similar to the cells used for sand filtration. If, in future, a better quality of raw water is fed to the filtration plant, the need for activated carbon beds would be eliminated. With appropriate planning in the initial design, the cells could be converted to conventional sand filters to increase future filtration capacity.

Impact on Water Quality: The adsorptive capacity of carbon is well known. The main questions regarding its effectiveness in curing the taste and odour problem are the cost, and the positioning of the carbon contactors in the water treatment sequence. A consultant's report (1) in December 1980, presented cost estimates and described the results of tests done in a pilot plant capable of treating 8.3 gallons per minute. Several treatment processes and sequences were tested. One sequence simulated existing treatment processes with the addition of granular activated carbon contactors. It was operated on August 6, 7 and 8, 1980, when the threshold odour numbers of the raw water were 25, 25 and 30 respectively. The objective set by the Buffalo Pound Lake Administration Board is 3 (anything higher indicates water that may be unpalatable to some). The water produced by the pilot plant had a TON of 2 for each of the three days.

By way of comparison, the TON for Buffalo Pound Lake raw water ranged from 6 to 30 in 1977, 1978, and 1979 and the water produced by the existing treatment plant varied from 3 to 10.

The above tests and TON results refer to water produced at the plant. The water must then be sent by pipeline to Regina and Moose Jaw and distributed in those centres. A question has been raised (11) regarding the existance of certain organisms in the pipeline and distribution system and the possibility that they may be significant sources of taste and odoour. The organisms feed on organic material and dissolved nutrients that may re-

main in the water after the treatment process. In February 1982, a fourth-year biology student found counts of actinomycetes of 10 to 1,000 organisms per millilitre in the drinking water of eight homes in Moose Jaw. In 1982, the Saskatchewan Research Council did not find actinomycetes in the pipeline and distribution system (4). If these organisms are present in sufficient numbers in the pipeline or distribution system, they could cause taste and odour after the treated water leaves the plant. However, the question must be considered as unanswered at this time.

The same source (11) stated that year-round operation (as opposed to summer operation) of a treatment system including GAC, would reduce the amount of nutrients and organic material entering the pipeline and restrict the growth of odour causing organisms downstream from the treatment plant.

Two quotes summarize the anticipated effects of a GAC process on water quality:-

"From the aesthetic point of view, the GAC process would solve the taste and odour problem, and from the safety point of view, would reduce the level of trihalomethanes in the finished water"(2)

- and -

"If the carbon filter operates continuously when water temperature in the pipeline exceeds 6^{o}C, then there is a reasonable probability of controlling taste and odour"(11).

Other Impacts : The addition of a GAC contactor to the present treatment process would mean no change in the present system for obtaining raw water. Consequently, the other impacts would be negligible. The regeneration of the carbon would produce wastes that must be disposed of. Presumably the facilities would be designed to meet requirements stipulated by the Saskatchewan Department of the Environment.

Adaptability to Future Needs and Other Uses: If, at some future date, a better raw water source should eliminate the need for GAC treatment, only 20% of the cost of the GAC works would be lost. The carbon contactor units could be converted to standard rapid sand filters when expanding plant capacity. The carbon media and regeneration facilities would have a salvage value.

Cost: The costs for this alternative would be as follows:-

Initial capital costs (millions of 1982 dollars)(1)(10)	
. GAC cells and materials	12.0
Present worth of future capital expenditures	
. GAC	11.3
. new intake and pumps	7.8
Present worth of operation, maintenance, and energy	
. O & M	13.5
. energy	10.1
Total present worth	54.7
Annualized cost	6.6

Capital Expenditure Summary (1)(10)

Year	Plant Capacity	GAC works	Intake works	Total
1983	32 mgd	12.0		12.0
1990	60	10.0	9.3	19.3
2000	75	5.5	1.6	7.1
2015	97.5	8.5	2.2	10.7
			TOTAL -	49.1

Note: For this estimate it is assumed that Regina goundwater will continue to be used for peaking in 1983. However, by year 2015, Regina groundwater will be phased out. The operation and energy costs are for summer operation only.

Time to Implement: The works could be designed, constructed and in operation within two years of the decision to proceed.

Other Considerations: Initially, a portion of the public may feel that the expenditure is not warranted considering that the only significant quality

improvement is in taste and odour. Those who now advocate a pipeline to Lake Diefenbaker would also be a source of discontent. However, once in place and producing good water, the GAC alternative would probably find general support.

Because the post-chlorination step (made necessary by the GAC step) will still be creating some trihalomethanes (although in much reduced quantities), there may be some people who will still question the safety of the finished product, whether or not it meets the accepted objectives.

5) Pipeline to Qu'Appelle River near Marquis:

Description: In this alternative, raw water would be taken from the Qu'Appelle River north of Marquis (a specific intake site has not yet been selected). A new intake structure would be required. It would be located and the lay-out arranged so as to permit some settlement of suspended material as well as to feed a new pumping plant. The pumps would drive the water through a 31 km buried pipeline (60" diameter) to the filtration plant. To meet present peak demands, 8,500 H.P. must be available to the pumps. By the year 2030, almost 19,000 H.P. would be required. At the plant, a pond would be built (about 100 acres in area and 21 feet deep) to serve two purposes. It would provide storage for about six day's operation of the filtration plant, and an opportunity for pre-chlorination and coagulation of suspended material.

The treatment process in the existing filtration plant would not be changed. Treatment facilities would be expanded from time to time to meet the growing demand.

Although it has heen demonstrated that mid-winter flow in the Qu'Appelle can be sustained by releases from Lake Diefenbaker, operating practise has been to stop those releases one or two months prior to spring break-up. If releases from Lake Diefenbaker before and during spring

break-up are not feasible, it would be necessary to have an alternate raw water source. Therefore, it is assumed that the present structure and pumping plant at Buffalo Pound Lake is retained in fully operable condition. It would likely be used every year between February and April. Winter water demands are lower than summer and there are no sudden peaks. The present intake capacity would be just sufficient to serve the average winter demand of 33.5 mgd in the year 2030 (see table 2).

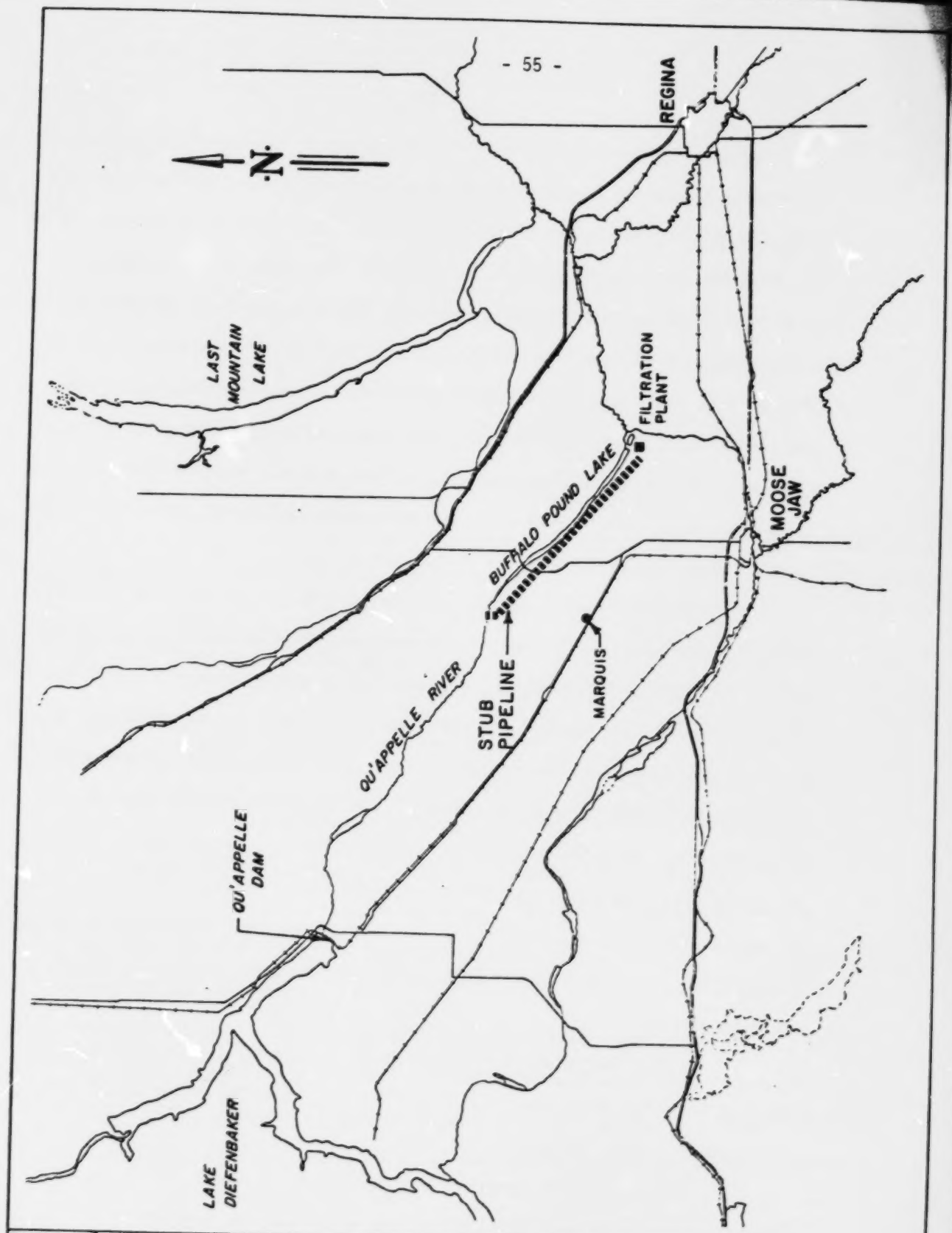
Impact on Water Quality: During the summer of 1980, CH2M Hill Ltd. (1) operated a pilot water treatment plant that could handle 8.3 gpm. Tanks of water were taken from the Qu'Appelle River near Marquis and run through the plant using the same treatment process as in the existing filtration plant.

As pointed out in the previous chapter, the water in the Qu'Appelle River is much lower in organic material than Buffalo Pound Lake. The raw water, even in mid-summer, had a low TON (threshold odour number) of only 2. After treatment, the finished water had a TON of 1. Both are below the TON objective of 3 set by the Buffalo Pound Administration Board for finished water. Since the treatment process did not include GAC contactors, there was no chlorine adsorption and no post-chlorination was necessary. One result was that the finished water was lower in trihalomethanes than the finished water from pilot plant tests for alternative 4.

The six-day detention pond would present an opportunity to provide even better water through flocculation and settlementof suspended material.

In late winter, Buffalo Pound Lake would continue to be the water source, however, it presents no serious taste and odour problem at that time of year.

Overall, this alternative offers very good quality treated water with no change in present treatment processes except the addition of six



DESIGNED / DRAWN / CHECKED	SUBMITTED _____ DATE _____ APPROVED _____ DATE _____ CHIEF ENGINEER PFRA	Government of Canada / Gouvernement du Canada — Regional Economic Expansion / Expansion Économique Régionale — PRAIRIE FARM REHABILITATION ADMINISTRATION ENGINEERING SERVICE	ALTERNATIVE 5 - PIPELINE TO QU'APPELLE RIVER NEAR MARQUIS — SCALE / DATE / SHEET OF

Figure 3

days raw water detention at the filtration plant. This detention can be used to improve treatment as described in alternative 7.

Other Impacts: It would not be possible to regulate the Qu'Appelle River flow at the exact rate needed for diversion to the filtration plant. Releases from Lake Diefenbaker would be higher than the diversion rate and the surplus would proceed to Buffalo Pound Lake. The surpluses must be large enough to ensure that there would be a supply available in the lake for winter withdrawal through the present intake. The amount of water flowing in and through Buffalo Pound Lake would be much less than for alternatives 4,7 or 8. Therefore, it is likely that over the years, the quality of the water in the lake would not be as good as for those alternatives.

The overflow of surplus waters into the Qu'Appelle River below Buffalo Pound Lake would be much less than for alternatives 4, 7 or 8. In fact, with careful management, there would be almost no imported water discharged from Buffalo Pound Lake. Therefore, it would not be necessary to consider downstream channel improvements as a necessary part of this alternative.

Adaptability to Future Needs and Other Uses: This alternative requires a 31 km pipeline and a new intake and pumping plant on the Qu'Appelle River (10). If future events were to lead to the construction of a pipeline all the way to Lake Diefenbaker, most of the 31 km would become part of the new pipeline. However, the investment in the Qu'Appelle River intake and pumping plant would be written off.

If in the future a regional water scheme should be constructed and used as a raw water source (alternative 3), both the pipeline and the intake would become redundant.

Clearly, once a pipeline alternative is accepted, there is a commitment to stay with that solution to the water quality problem.

For this alternative, all of the present capacity of the Upper Qu'Appelle Rivee would be reserved to serve possible demands at the new intake. From time to time there may be surplus capacity available to deliver water for other needs along the Qu'Appelle (recreation, wildlife, and agriculture) but no guarantees could be made. In some respects an unreliable supply is worse than no supply at all. Consequently, it could be stated that this alternative precludes other uses of imported water along the Qu'Appelle system unless the Upper Qu'Appelle River channel capacity is enlarged for that purpose.

Costs: The costs for this alternative would be as follows:-

Initial capital costs (1982 dollars)	
. pipeline, intake, pumps, pond and other works (10)	$53.0 million
Present worth of future capital expenditures	
. additional pumping capacity	2.5
Present worth of operation, maintenance and energy	
. pipeline and pumphouses	7.9
. pumping energy	17.8
Total present worth	81.2
Annualized cost	9.8

Note: the PFRA estimate (10) was increased by a small amount to cover the construction of a six-day detention pond.

Time Required for Implementation: Design, construction, and commissioning of the intake works would require two years. A similar period would be more than sufficient for design, securing right-of-way, installation, and commissioning of the pipeline.

Other Observations: The maintenance and operation of two intake structures, one on the Qu'Appelle River and one on Buffalo Pound Lake, would provide flexibility but would also increase costs. The cost estimates account for pumping costs at either intake, but the ordinary maintenance for the Buffalo Pound Lake intake was not included.

It has been suggested that consumers may notice a change in water quality if it is necessary to switch from the river intake to the lake intake in late winter. Most of the time the water from the lake intake would have a higher TDS and hardness.

6) Canal to Qu'Appelle River near Marquis:

Description: This alternative would include an intake structure on the Qu' Appelle River north of Marquis and a short pipeline to take the water to the top of the valley (10). From there, a 35 km open canal would convey the water to the filtration plant. By the year 2030, 10,500 H.P. would be needed to lift the waters from the Qu'Appelle River to the canal. In all other respects, the description of the scheme would be identical to alternative 5.

From an operations point of view, it is likely that the backup intake in Buffalo Pound Lake would be used for a longer period than in alternative 5. Icing in the river, and in the canal, would increase the reliance on the Buffalo Pound intake in late winter.

Impact on Water Quality: The quality of the water delivered to the plant would be slightly inferior to that delivered by the pipeline in alternative 5. There would be some pick-up of salts in the canal. However, experience in Alberta with canals in similar soils indicates that the change in quality is very small. There could be a problem of weed control in the canal. The fact that the Buffalo Pound intake would be used for a longer winter period would also lower the average quality of the finished water, but only a little.

Except for these minor differences, the finished water would be the same as in alternative 5.

Other Impacts: Same as alternative 5 except for severance problems.

Adaptability to Future Needs and Other Uses: This alternative requires a 35 km canal, and a new intake and pumping plant on the Qu'Appelle River.

If future events should lead to the construction of a pipeline to Lake Diefenbaker, the only investment that could be salvaged would be the canal right-of-way, the graded canal bed for laying the pipe, and the six-day detention pond.

If a future decision were made to run an open canal all the way from Lake Diefenbaker to the filtration plant, it is likely that the location and grade of the short canal would not match the longer canal. Again, only the detention pond would be salvaged.

This alternative would require full commitment of the present capacity of the Upper Qu'Appelle River for the reasons given in alternative 5.

Costs: The costs for this alternative would be as follows:-

Initial capital costs (millions of 1982 dollars)(10)	
. canals, right-of-way, etc.	9.0
. main pumping plant, intake, weir, pipe	8.3
. other pumping facilities, internal reservoirs	12.1
Present worth of future capital	
. additions to pumping capacity	2.1
Present worth of operation, maintenance and energy	
. operation and maintenance	8.6
. energy	20.8
Total present worth	60.9
Annualized cost	7.3

Time Required for Implementation: Design, construction, and commissioning of the intake works would require two years. A similar period would be more than sufficient for design, securing right-of-way, installation and commissioning of the pipeline.

Other Observations: As explained in alternative 5, ordinary maintenance costs for the Buffalo Pound Lake intake have not been included.

Because the canal supply system would be affected by ice, the Buffalo Pound intake would be used for a longer period in winter. If the change from river water to lake water is detectable, the consumer would be aware of the change for a longer period each winter than in alternative 5. The lake water has a higher TDS (total dissolved solids) and hardness most of the time.

7) Detention Pond:

Description: For this alternative, a pond would be constructed near the filtration plant to store a six-day supply of water. By the year 2030, a peak (mid-summer) six-day supply would be about 429 million gallons (1,577 acre feet or 1,884 dam^3). Chemicals would be introduced as the water entered the pond to kill algae and other organisms. A six-day detention time would permit most of the dead organisms to settle. The discharge from the pond would proceed through the filtration plant using present processes.

The pond would be about 100 acres in area and average 21 feet deep. That would provide storage for 429 million gallons with an allowance of 5 feet for ice cover on top and dead storage at the bottom. Some alterations and additions to the present pipeline from Buffalo Pound Lake to the filtration plant would be needed so that water could be fed to the pond, or directly to the plant. Also, a new pumping unit would be required to move the water from the pond to the filtration plant.

The comments on this alternative have been written assuming that a detention pond with chemical addition would be the only new process. Actually, a detention pond would be most effective if used in conjunction with GAC contactors. What one process would miss, the other may remove.

Impact on Water Quality: Based on a literature search and discussions with a few centres using detention ponds, Saskatchewan Environment staff (13) commented on six-day detention with copper sulphate treatment as follows:-

"Difficulties inherent in the proposed type of system include:

1) Treatment is often a "hit and miss" proposition with no real effectiveness guarantee. The degree of algae control is largely dependent upon the exact timing of chemical application which can only be determined through constant quality monitoring during the problem period.

2) Although the proposed system can be expected to reduce trihalomethane formation upon disinfection, it is doubtful that an equivalent reduction of algae toxins could be achieved.

3) Sources of taste and odour not attributable to algae growth will not be affected to any large extent, however, reservoir aeration may improve overall raw water quality to some degree.

Even though a retention pond system could be expected to improve taste and odour problems associated with the treated water, such an enterprise can still be considered somewhat of a gamble due to operational uncertainties. If optimum treatment parameters are not given adequate attention, taste and odour problems will recur with the severity of those experienced in the past."

Saskatchewan Environment suggested that the role of a detention pond would be to serve as one component of a comprehensive program that could also include carbon contactors, and periodic cleaning of the distribution system.

Other Impacts: With adequate design, this alternative would have no significant impact on anything other than the treatment process.

Adaptability to Future Needs and Other Uses: Alternatives 1, 2, 3, 5 and 6 envisage the supply of water to the filtration plant by pipeline or canal. Each of those schemes include a detention pond to ensure a continuous supply to the filtration plant during short periods of breakdown or maintenance on the canal or pipeline system. A detention pond would also serve peak demands that exceed the capacity of the pipeline or canal. Consequently, investment in a detention pond for water quality improvement, if properly located, would be fully utilized by any canal or pipeline alternative constructed subsequently.

Costs: The estimated cost has been based on a pond large enough to provide a six-day detention in the year 2030. It would be less costly to build the pond to suit present demands and expand it from time to time.

As part of alternative 1, PFRA estimated the cost of a detention pond having a capacity of 580 dam^3. That capacity would be used to supply

the peak day demand in 2030 when the inflow is equal to the average for the highest six days (but it would not provide six day's detention). The cost figures below were obtained by scaling up that cost estimate to a storage of 1,884 dam^3. Costs for chemical treatment, pipes, and valves were estimated very approximately.

Initial capital costs (1982 dollars)(10)	
. pond (construct half size in 1982)	$2.6 millions
. pumping station and appurtenances	2.7
. works for chemical addition	0.5
Present worth of future capital expenditures	
. double size of pond in 2005	0.6
. new intake and pumps	7.8
Present worth of operation, maintenance and energy	
. detention pond	0.3
. pumping from Buffalo Pound Lake	10.3
Total present worth	24.8
Annualized cost	3.0

Capital Expenditure Summary

Year	Detention Pond	Buffalo Pound Lake intake	Total
1983	2.6		2.6
1990		9.3	9.3
2000		1.6	1.6
2005	2.6		2.6
2015		2.2	2.2
		TOTAL -	18.3

Time Required for Implementation: Construction of the pond and installation of the necessary piping, valves, and pumps could be completed within a two-year period.

Other Observations: By itself, this alternative cannot guarantee removal of taste and odour. There would be some improvement. However, frequent changes

would be required in the kind and level of treatment to match the kind and level of organic material in the raw water. Perfect operation cannot be assumed, and it is probable that there would be periods of unacceptable taste and odour - although such periods would be less frequent. The public would probably notice the periods with high TON and not the periods of improvement. Their overall perception would be that the problem was not solved and the investment in the works was wasted.

Nevertheless, the detention pond is a desirable part of any solution. It is mandatory to have the balancing storage for the pipeline or canal schemes, and it would increase the effectiveness of the GAC contactors in alternative 4.

8) Increased Qu'Appelle Flow

Description: For this alternative water is delivered from Lake Diefenbaker to Buffalo Pound Lake using the full channel capacity of the Qu'Appelle River every year. The present intake in Buffalo Pound Lake would be enlarged to serve the growing treatment facilities. Treatment processes would not be changed.

Since 1959, South Saskatchewan River water has been fed into the Qu'Appelle River to sustain water levels in Buffalo Pound Lake. The structure for releasing water from Lake Diefenbaker through the Qu'Appelle Dam has a capacity of about 37 M^3/sec (1,300 cfs.) even when Lake Diefenbaker is at its lowest operating level. However, the channel capacity of the river from there to Buffalo Pound Lake is only 11.3 M^3/sec (400 cfs) except when reduced by weeds or ice (3). The full capacity of the delivery system has been used in only one year, 1981, when 143,000 dam^3 were delivered to Buffalo Pound Lake (8).

Impact on Water Quality: During the summer of 1981, the taste and odour problem was minimal or non-existant. The concentrations of algal organisms in Buffalo Pound Lake were much below previous (and subsequent) years. The concentration of total dissolved solids was decreased. One could speculate that the improvement in water quality was due to the increased flow of good quality water from Lake Diefenbaker into and through Buffalo Pound Lake. Since other factors may have been at work and no expert analysis has been reported on this matter, the reason for the improvement in water quality must be described as "conjecture" rather than "known".

Assuming that the above conjecture is correct, continued operation of the Upper Qu'Appelle River at capacity would provide some further improvement in water quality and sustain it. The improvement would be sufficient to reduce taste and odour to barely noticeable levels with existing treatment facilities. There would be some reduction in undesirable by-products of organic decomposition and chlorination because of the reduced concentration of organics in the raw water.

Other Impacts: When the Upper Qu'Appelle River flows are near capacity,a portion of the flow must pass through Buffalo Pound Lake and move downstream in the Qu'Appelle River to Lumsden, Craven, Fort Qu'Appelle and eastward. In a dry year, when Last Mountain Lake is low, surplus water can be directed there rather than exceeding the very small river channel capacity from Craven to Pasqua Lake of 4.2 M^3/sec or 150 cfs(3). However, if Last Mountain Lake cannot accept more water, or if natural run-off from Moose Jaw, Wascana, Boggy, and Flying Creeks is already filling the channel, imported water from Lake Diefenbaker just adds to a serious water management problem. For this reason, the cost estimate for this alternative includes the cost of building and main-

taining a Qu'Appelle River channel capacity of 14.2 M^3/sec (500 cfs) from the Buffalo Pound Lake dam to Highway 56 below Lake Katepwa.

This alternative would also have a flushing effect on Buffalo Pound Lake. It is not known what impact this would have on the quality of the Qu'Appelle River downstream. Whatever the effect would be upstream from Lumsden, it would probably be beneficial downstream. During dry periods, flows at Lumsden are mostly effluent from Regina's sewage treatment system and the imported water would dilute it.

Another dry year impact would be the improved recreation resulting from topping up the seven recreational lakes in the Qu'Appelle Valley. Conversely, in wet years, the imported water would add a small amount to the flood problem.

Adaptability to Future Needs and Other Uses: This alternative requires fewer irreversible commitments than the others. If, in future, other supply systems became available, alternative 8 could be abandoned with little loss. The only investment that might be made unnecessary would be the expansion to the intake in Buffalo Pound Lake. The channel improvements from Craven to Pasqua Lake have already been justified to reduce the duration of high water in Last Mountain Lake and in the Qu'Appelle Valley from Craven to Pasqua Lake (9).

Cost: The costs of this alternative would be as follows:-

Initial capital costs (millions of 1982 dollars)	
. Qu'Appelle River channel improvement (9)	4.75
Present worth of future capital expenditures (10)(2)	
. new intake works and pumps	7.8
Present worth of operation and maintenance and energy	16.0
Total present worth	23.8
Annualized cost	2.87

Capital Expenditure Summary (10) (millions of 1982 dollars)

1982 to 1985	channel improvement	4.75
1990	new intake and pumps	9.3
2000	more pumps	1.6
2015	more pumps	2.2
	TOTAL -	17.9

Time Required for Implementation: The enlarged intake works can be constructed as required, but a decision must be made very soon as to where the intake will be built. The channel improvements from Craven to Pasqua Lake would take about five years to complete, two years to secure right-of-way, and three years to construct.

Therefore, the scheme can be considered as one that can be implemented immediately when water levels and run-off are low, or in five years if not.

Other Observations: Residents of the Qu'Appelle Valley between Craven and Pasqua Lake, in particular those representing the Indian Reserves, are not convinced that the channel should be improved. It would probably be necessary to use expropriation to secure right-of-way and a strong public reaction can be predicted, some for, but many against.

Without the channel improvements, the solution is not really viable.

VI. CHOOSING A SOLUTION

Eight alternatives were discussed in the previous chapter:

1) Pipeline to Lake Diefenbaker;

2) Canal to Lake Diefenbaker;

3) Regional Water Scheme

4) Present supply system with addition of granular activated carbon contactors;

5) Pipeline to Qu'Appelle River near Marquis;

6) Canal to Qu'Appelle River near Marquis;

7) Detention pond;

8) Increased Qu'Appelle flow.

Some of these alternatives can be deleted from further consideration for various reasons as follows:-

Alternative 8) will improve water quality, but may not achieve the desired level of improvement. It can be implemented only if there is adequate channel capacity and day-by-day water management in the Qu'Appelle Valley. Already, many years of effort by the Qu'Appelle Implementation Board and its predecessors have not resulted in reaching agreement on necessary improvements to the critical reach between Craven and Pasqua Lake. Although the works could be built in two or three years, concensus to proceed is not likely to be achieved within a reasonable time.

Alternative 7) is not a solution by itself because of the difficulty of keeping treatment chemicals in balance with the rapidly changing mix and concentration of organisms in the intake water. A detention pond may be part of another solution but is not a solution by itself.

The Alternative 2) canal from Lake Diefenbaker to the filtration plant would lead to demands from the public for agricultural water en route.

A canal, unlike a pipeline, is exposed to public view. In a dry year, a stream of good water flowing through drought-stricken fields would generate public pressure for irrigation. That would require an enlarged canal, and would, in time, change the scheme to alternative 3.

Alternatives 5) and 6) have three problems in common that justify setting them aside:

- they use Buffalo Pound Lake as a source during all or part of the winter;
- there is periodic bacteriological contamination of the Upper Qu'Appelle River from non-human sources;
- if irrigation were developed between Marquis and Lake Diefenbaker, the return flows, with elevated salt levels, would return to the Qu'Appelle River above the Marquis intake. The 140,000 acre irrigation potential, recently identified by PFRA, is less than the present one million, and potential for two or three million acres in Alberta upstream from Lake Diefenbaker, but the return flows in Alberta will receive more dilution from natural run-off.

The remaining three alternatives, ranked according to the quality of water they would supply, are as follows:-

Alternative	Water Quality	Annualized Cost
1. Pipeline to Lake Diefenbaker	Best water	$17.7 millions
2. Regional water scheme	Almost as good	8.6
3. Present supply system with addition of granular activated carbon contactors	Acceptable	6.6

The annualized cost shown above for the regional scheme, is based on the assumption that canals, reservoirs, intakes, and so on would be sized at the outset to allow for full development, and that 20% of the costs would be charged to Regina-Moose Jaw water supply, because, ultimately, they would draw 20% of the water. PFRA has reported on a scaled-down canal (10) that would supply the year 2030 demands of the cities and no other uses. The

annualized cost of such a scheme was not computed by PFRA, but it would be about $18,000,000.00.

Therefore, on its own, the annualized cost of the canal scheme is comparable with the pipeline. The canal scheme would use a new reservoir near the filtration plant for winter supply. There is a minor degree of uncertainty as to the effect such a reservoir might have on water quality.

The municipal supply share of the total annualized cost of a large regional scheme is half that of the pipeline and the water is almost as good. However, the construction period for the regional scheme is a minimum of five years, rather than two for the pipeline. Further, a federal commitment would probably be needed before implementation of the regional scheme could begin. One must ask whether the citizens of Regina and Moose Jaw are prepared to wait through five or more summers of bad water. It is likely that the regional scheme would not be accepted as a solution unless immediate expenditures were made to install granular activated carbon contactors. That approach would work but it reduces the cost advantage. Also it is dependent upon decisions (over which the province has no control) by the federal government and the cities.

These considerations lead to the conclusion that the pipeline is the most costly alternative but it may be the best if there must be:

(a) a long-term solution unaffected by other future developments and decisions;

(b) a solution in place within two years;

and (c) a solution that provides "best" rather than just "acceptable" water.

Even so, I fully support the large regional scheme. Future development for irrigation, industry, recreation and other purposes of the River-

hurst-Moose Jaw-Regina corridor, and indeed the Souris Basin, will require an assured water supply. Federal/provincial discussions should begin as soon as possible to sort out their respective roles in the financing and implementation of larger regional economic development for Southeastern Saskatchewan. Irrigation expansion in my opinion is of great importance in achieving that goal.

NUMBER	ALTERNATIVE	IMPACT ON WATER QUALITY	
		KNOWN	CONJECTURE
1	Pipeline to Lake Diefenbaker	Provides the best quality raw water. Given equal treatment would provide the best quality finished water. Contains algae and, occasionally, coliforms and other bacteria, but concentrations are very low. Treatment is straightforward because of low concentrations and low variability.	There is a need to understand long-term changes that may occur in Lake Diefenbaker. In the short-term (say thirty years), there is no problem. In the long-term, quality may suffer from upstream irrigation return flows, municipal effluent loadings, and consequent increase in algae. Even so, it would still be the best quality source.
2	Canal to Lake Diefenbaker	Raw water quality is marginally less than for alternative 1, except for a period in winter when Buffalo Pound Lake would be used as a source. Would require rigorous enforcement of environmental controls to minimize bacteriological contamination along the canal route.	Same as alternative 1 regarding possible long-term changes in Lake Diefenbaker water quality.
3	Regional Water Scheme	Raw water quality is marginally less than for alternative 1. Winter supply from new reservoir would be better than from Buffalo Pound Lake, but not as good as from the Diefenbaker pipeline. Would require rigourous enforcement of environmental controls to minimize bacteriological contamination along the canal route and at the new reservoir.	Same as alternative 1 regarding possible long-term changes in Lake Diefenbaker water quality.
4	Granular activated carbon filters	Water source is Buffalo Pound Lake. GAC removes taste and odour caused by products of algal decay, reduces taste and odour caused by bacterial activity, reduces concentrations of trihalomethanes and algal toxins.	Some taste and odour may be caused by actinomycetes in the distribution system. If so, this alternative would be less effective. The Saskatchewan Research Council found no actinomycetes in the distribution system in 1981 and 1982. Future quality of Buffalo Pound Lake may be affected by return flows from upstream irrigation.
5	Pipeline to Qu'Appelle River near Marquis	Raw water almost as good as Lake Deifenbaker although more turbidity. Pilot plant tests in 1980 using present treatment processes produced fully acceptable water with TUN of 1 and very low THM (less than 4 ppb). Occasional high coliform counts from wildlife and livestock.	Use of Buffalo Pound intake in winter may be necessary with corresponding change in water quality. Return flows from proposed irrigation developments would increase the total dissolved solids in the Qu'Appelle River from 250 ppm to, perhaps, 400 or more at some times of the year.
6	Canal to Qu'Appelle River near Marquis	Raw water marginally lower than in alternative 5 though no significant difference after treatment. Use of Buffalo Pound intake in winter would be necessary with corresponding change in water quality.	Return flows from proposed irrigation developments would increase the TDS in the Qu'Appelle River from 250 ppm to, perhaps, 400 or more at some times of the year.
7	Detention Pond	Provides an opportunity to remove algae and other organisms before water enters the treatment plant. Reduces THM production but perhaps not algal toxins.	Treatment may be "hit and miss" because timing of chemical application must match the ever-changing kinds and concentrations of algae and other organisms.
8	Increased Qu'Appelle flow	In 1981, treated water had a threshold odour number of less than 6 compared with the objective of 3 and highs of 8, 8, 10, and 10 in the years 1976 to 1979 respectively. That year the delivery of water from Lake Diefenbaker to Buffalo Pound Lake was larger than in any previous year.	Perhaps the higher flows in 1981 were the reason for the lower taste and odour, although the situation is too complex to be certain. Over the long term, return flows from proposed irrigation projects would add salts to the Qu'Appelle River before it enters Buffalo Pound Lake.

TABLE 5

COMPARISON OF ALTERNATIVES

ADAPTABILITY TO FUTURE NEEDS AND OTHER USES	OTHER IMPACTS	ANNUALIZED COST MILLIONS OF 1982 DOLLARS	TIME TO IMPLEMENT
Provides only for municipal use at Regina and Moose Jaw and towns near the pipeline route. If a lower cost supply of water became available in the future (say alternative 3), it is not likely that the pipeline system would be abandoned, and costs would remain high.	Because of competition for available capital, construction of this scheme would delay or preclude the regional water scheme. By the year 2030, a 60" pipeline would require 49,000 H.P. to drive the water through it, 20% of the generating capacity at Coteau Creek.	17.7	Two years
Provides only for municipal uses at Regina and Moose Jaw. Other uses could not be served. If a regional water scheme were developed, a portion of the investment in pumps, canal, intake, and right-of-way would be salvaged.	By the year 2030, 10,000 H.P. would be needed to lift the lake water into the canal. That is only 20% of the power required for alternative 1.	18.0 (approximately)	Two years
This alternative provides the greatest capability for supplying present and future water demands for all purposes in the Regina-Moose Jaw area and surrounding region.	Return flows from proposed irrigation projects will improve supply to the Qu'Appelle in dry years, but may require channel improvements from Craven to Pasqua Lake to handle augmented flows in wet years. Return flows will have higher TDS than Lake Diefenbaker releases, but would probably be of better quality than the natural low flows into the Qu'Appelle River. By the year 2030, 49,000 H.P. would be needed to lift the water into the main canals for all uses.	8.6 (20%)	Five years
If a better raw water source becomes available soon, 80% of capital expenditures could be salvaged by converting to conventional sand filters. If a better water source becomes available after a new Buffalo Pound intake is built, none of the expenditure on that intake would be salvaged.	Facilities must be built to dispose of the wastes arising from contactor backwashing and carbon regeneration. From 1982 to 2030, the power required at the intake would increase from 2500 HP to 9000 HP.	6.6	Two years
Most of the 31 km pipeline could be incorporated in a future pipeline to Lake Diefenbaker. The intake and pumping plant would be written off. If alternative 3 were constructed, all these works would be abandoned.	With no change in the river's channel capacity, less water would flow to Buffalo Pound Lake causing a quality decline. The decreased flow may preclude other uses of imported water upstream of the junction with Wascana Creek. 19,000 H.P. required in year 2030.	9.8	Two years
A future pipeline to Lake Diefenbaker might make use of the canal bed and right-of-way. If alternative 3 were constructed, all these works would be abandoned.	Same as alternative 5 except that 10,400 H.P. required in year 2030.	7.3	Two years
Would be an integral part alternatives 1, 2, 5 and 6. Probably needed for alternative 3 and would be complimentary to alternative 4. If a better source of raw water became available, the new intake built in Buffalo Pound Lake would be written off.	None	3.0	Two years
As time goes on, future demands for water in and near the Qu'Appelle Valley will require increased water delivery from Lake Diefenbaker through Buffalo Pound Lake. Within twenty years, the demand in every year may be as much as the flow in 1981. A new intake is needed soon at Buffalo Pound Lake. If other supply systems become available, the intake would be abandoned.	In dry years, there would be a beneficial effect on downstream water quality and lake levels. In wet years, it would aggravate a difficult water management problem even though the project as proposed here includes channel improvement from Craven to Pasqua Lake.	2.9	Five years.

APPENDIX 1

APPENDIX I

IMPLEMENTATION PROCESSES

After an alternative has been selected, one must consider what administration machinery is available to proceed with it.

The provincial role in alternative 4 (GAC) could be handled by present granting processes administered by the Department of Urban Affairs and discussed later in this chapter. However, for the other two alternatives, water will eventually be delivered to customers other than Regina and Moose Jaw, and it would be wise for the province to retain a management role. With this in mind, it was felt that each of the viable alternatives would require a different administrative approach.

1) For the pipeline project:

There are three management options for building and management of a pipeline - public sector, private sector, and mixed.

For the public section option, funds would be channelled to the Saskatchewan Water Supply Board (SWSB), an existing Crown Corporation which would manage contracts for the design and construction of the project. When the works are complete and commissioned, the SWSB would assume continuing responsibility for the project and would sell water to the cities and to industrial customers. The water rate would be set to cover costs of operation, maintenance and debt servicing. It is assumed that a portion of the provincial input would be a grant. The rates charged to the cities would be based on the cost of serving the remaining debt plus operation and maintenance. The cities would increase their water rates to pay for their capital input and to pay the SWSB for the raw water. If Federal financial input is available, that would further reduce the water rates.

For the private sector option, a corporation would be selected to build and operate the pipeline as a utility. It would receive federal

grants (if any), the grant portion of the provincial contribution, and whatever amount the cities wish to invest in initial costs. The balance of the funds required would be provided by the corporation. The rates set by the corporation would be based on recovering operation, maintenance and business costs plus a return on their equity. An essential feature of this option would be an agreement by both senior governments to rebate income tax to the company. Otherwise the gross return on equity must be doubled so that, after taxes, the net return would be satisfactory. Federal law now permits such rebates to utilities selling electricity or steam. Amendments to the legislation would be needed to include water. New provincial legislation would be needed to permit rebate of the provincial income tax.

The mixed option would see the project constructed and operated by a consortium, consisting of a selected private corporation and the SWSB. The equity position of the SWSB would be determined by the size of the federal (if any) and provincial grants. It is likely that a corporation would want an equity of at least $20 million in order to justify its participation in operation and mangement. Any remaining funds required forthe project could be borrowed by the province or by the corporation. The project could be constructed and managed by the corporation for the consortium, or by the SWSB (although if SWSB is to operate the project, the public sector option makes more sense). Water would be sold to cities and industries at rates that would cover operation, maintenance, and business costs, and a satisfactory net return on the corporate equity. As mentioned for the previous option, there must be a federal/provincial commitment to rebate income taxes.

2) For the Regional Water Scheme:

A federal commitment to a regional water scheme would most likely include direct participation in design and construction. Using the Gardiner Dam Project and irrigation works in Alberta as precedents, a federal-provincial board could be established to oversee the project generally. The PFRA would

be a likely choice to build the main works and operate them for, say, ten years. Thereafter the province, represented by the SWSB, would take over and operate the works. Water would be sold by the SWSB to cities, to industries, to government departments (for example, to Agriculture for irrigation) and to other entities such as Ducks Unlimited. The rates charged for water would cover the operation and maintenance costs, and servicing of any provincial debt (assuming the province would wish to recover expenditures on land purchases, right-of-way for the project, detention pond and pumping works near the filtration plant, or other like expenditures)

3) For the addition of granular activated carbon contactors:

A provincial grant for this project could be paid directly to the cities of Regina and Moose Jaw. They already have a joint Board to administer the Buffalo Pound water system. That Board could manage contracts to implement the project.

Municipalities should pay a reasonable part of the cost of water and sewage facilities. It is not for this report to determine what "reasonable" should be. It has been suggested elsewhere (13) that municipalities can be expected to pay the entire cost of such works up to some limit, say $200 per capita accumulated from a date to be chosen. Provincial grants would cover costs in excess of that amount. In the case of Regina and Moose Jaw, the combined population @ $200 per capita yields $38,000,000.00. The amount available for financing a new project would be some portion of that figure, depending upon the date selected for computing the cities' accumulated expenditures. Costs in excess of the computed amount would be covered by provincial grants.

APPENDIX 2

APPENDIX 2

PRINCIPAL REFERENCES

1. "Water Treatment System Improvement and Expansion Studies" by CH2M Hill Canada Ltd., for the Buffalo Pound Water Administration Board, December 1980.

2. "Regina - Moose Jaw Long Term Water Supply Study, Phase 1" prepared by PFRA for the Steering Committee representing Regina, Moose Jaw, Saskatchewan Environment, Saskatchewan Urban Affairs, and PFRA. February 1982.

3. Letter to consultant from Saskatchewan Environment dated October 27, 1982.

4. Report to PFRA on water quality in Lake Diefenbaker and selected sites in the Upper Qu'Appelle River, November 1982, by M.R.2 Consulting Engineers.

5. Verbal communication from Alberta Department of Environment.

6. "Interprovincial Water Quality Data at PPWB Monitoring Stations" 1980. Prepared and published by the Prairie Provinces Water Board.

7. Letter to Minister of Urban Affairs from Water Assistance Grants Branch, October 27, 1981.

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11. "A Report on the Potential Source of Earthy-Musty Odours in Regina - Moose Jaw Drinking Water and its Control" by Dr. D. R. Cullimore, Regina Water Research Institute Report # 34, September 1, 1982.

12. "Water in Saskatchewan: Problems, Issues, and Management for the future" prepared for Saskatchewan Environment by E.F. Durrant Water Resource Consultants Ltd., March 1982.

13. Notes on Detention Ponds prepared by Saskatchewan Environment for Gerald Muirhead, M.L.A., October 4, 1982.

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14. "Algae Analysis of Buffalo Pound Lake samples" prepared by Saskatchewan Environment, Water Pollution Control Branch, September 29, 1982.

15. "The Hazards of Using Point-of-use water treatment devices employing activated carbon" by Bureau of Chemical Hazards, Environmental Health Directorate, Health Protection Branch, Health and Welfare, Canada, December 1980.

16. "Briefing paper on Petition CP 78-19: request for commission action to ban home-use water filters containing activated carbon and no bacteriostat" prepared by Robert Miller, Office of Program Management, U.S. Consumer Product Safety Commission, June 1979.

17. "Introduction to taste and odour control in municipal water treatment using activated carbon" prepared by Saskatchewan Environment, Water Pollution Control Branch, September 1982.

18. Letter from W. A. Meneley Consultants Ltd. to Gerald Muirhead, M.L.A. regarding Regina water supply, September 28, 1982.

19. "Preliminary Proposal, Lake Diefenbaker Water Line" by Interprovincial Pipeline Ltd., November 1982.

20. Letter from Alberta Oil Sands Pipeline Ltd. to Gerald Muirhead dated September 30, 1982, setting out general conditions under which the company would build a 1,000,000 66l/day water line (26.2 mgd).

21. Letter from Alberta Oil Sands Ltd. to Gerald Muirhead dated October 22, 1982, containing a proposal for the construction of a pipeline.

22. Letter from Alberta Oil Sands Ltd. to Gerald Muirhead enclosing information regarding Federal and Alberta legislation for relating income tax to electrical and steam utilities.

23. Executive Summary of Canada Engineering Report on "Regina - Moose Jaw water supply study, Lake Diefenbaker to Buffalo Pound Pipeline", October 1982.

24. "Municipal Water Supply Considerations - Buffalo Pound Lake" prepared by Water Pollution Control Branch, Environment Saskatchewan, September 1977.

APPENDIX 3

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September 28, 1982

Mr. Gerald Muirhead, Esq. M.L.A.
Member of the Legislative Assembly
Legislative Building
Regina, Saskatchewan
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Regina Water Supply

Dear Mr. Muirhead:

In your consideration of water supply alternatives for the City of Regina I feel that the following factors will be of importance, not only to provide Regina with a decisively-better water supply, but also to rationalize the government's decision in the context of demands for water supply assistance from other communities in the province.

The long-term strategy should be to supply the City of Regina with an adequate supply of excellent quality water for municipal purposes. Any interim tactical solutions must contribute toward achieving the long-term goal.

I have deliberately confined my discussion to the water supply for Regina only. The merits of Moose Jaw's case for water assistance should be considered separately.

1. Water Quality:

The City of Regina must have a supply of better quality water that is, water that not only has a better taste and odor, but also water that has a lower concentration of chemical consituents and lower hardness. I dont have any definitive information on taste and odor but Table 1 compares the chemical composition of Saskatoon water, Buffalo Pound Lake water, Regina groundwater and Nokomis groundwater.

The proposed carbon filter system inherently cannot improve the chemical quality of the water. Therefore, I cannot support that solution because it does not contribute to the strategic goal.

The chemical quality of the water coming from Buffalo Pound Lake is governed by the physical setting of Buffalo Pound Lake in the Qu"Appelle Valley. The Qu'Appelle Valley is a groundwater discharge area. That is, the precipitation that falls on the upland adjacent to the valley soaks into the ground, moves downward and laterally, and discharges into the Qu'Appelle Valley. As water moves through the ground it dissolves chemical constituents from our fertile soils, so that by the time that the groundwater discharges into the valley it may contain 2,000 to 3,000 ppm (parts per million) of chemical constituents.

Groundwater discharge, together with local surface runoff into the valley constituted the original source of water supply for Eyebrow Lake and Buffalo Pound Lake. Evaporation from those lakes during the summer months removed water from the system, leaving the chemical constituents behind. After Gardiner Dam was built, excellent quality water could be diverted from Diefenbaker Lake but a canal had to be built around Eyebrow Lake to avoid picking up excessive salts from that segment of the valley. Nevertheless, salts are still being added to Buffalo Pound Lake by groundwater discharge and local overland runoff, and these salts are still being concentrated by evaporation from Buffalo Pound Lake. This accounts for the higher mineralization and hardness in the water at Buffalo Pound Lake shown in Table 1.

Any surface conveyance system from Diefenbaker Lake to Regina inherently must degrade the chemical quality of the water delivered and hence does not support the strategic objective.

It has been suggested that a high-level canal be constructed from Diefenbaker Lake to Regina. Such a system would still require extensive storage facilities because a canal for municipal water supply needs could not be operated during the winter due to freezing. Such a system would be comparable to the Saskatoon Southeast Water Supply System. That system has been plagued by chemical quality problems and by taste and odor problems from the outset. (Talk to the Town of Lanigan about their experience with this sort of system).

Furthermore, any surface conveyance system for all or part of the route for the Regina water supply would create the same situation that now exists, namely, the presence of offensive and intractable taste and odor problems.

THEREFORE, I CONCLUDE THAT ON WATER QUALITY GROUNDS ALONE THAT THE ONLY VIABLE CONVEYANCE SYSTEM FOR TRANSPORTING WATER FROM DIEFENBAKER LAKE TO REGINA IS BY PIPELINE FOR THE ENTIRE ROUTE.

2. Amount of Water Diverted:

The amount of water to be diverted from the Saskatchewan River System must be sufficient to satisfy the strategic objective - to supply the City of Regina with good quality water for its municipal needs.

These needs should not include provision of water for large industrial consumers or for irrigation. These should be considered separately. The capital and operating costs of supplying the additional water for industrial and agricultural needs should be identified so that they may be recovered from the sale of water for these uses.

Any water diverted from the Saskatchewan River System is a consumptive use insofar as the river system is concerned, that is, the water is removed from the system and never returned to it in any form. Thus, any consumptive use reduces the capability for power generation or other uses downstream and that foregone benefit must be considered as part of the cost of the diversion.

I dont know the amount of water now diverted by the City of Regina through the existing Buffalo Pound Lake System. However, if it is assumed that the current municipal water consumption is about 125 Imperial Gallons per capita day, and that the population is about 150,000 people then the annual average daily consumption would be about:

$$125 \times 150{,}000 = 18{,}750{,}000 \text{ Imperial Gallons}$$
$$= 68.87 \text{ acre.ft/day}$$
$$= 84{,}950 \text{ cubic metres/day}$$

On an annual basis:

$$365 \times 125 \times 150{,}000 = 6{,}843{,}750{,}000 \text{ Imperial gallons per yr}$$
$$= 25{,}137 \text{ acre.ft/yr}$$
$$= 31{,}006{,}950 \text{ cubic metres/yr}$$

The surface area of Diefenbaker Lake is 106,000 acres at full supply elevation according to (PFRA, 1979), so the required diversion to Regina would amount to about 3 inches of water off the top of the reservoir.

In the original design of the South Saskatchewan River Dam and Associated Works, provision was made for diversion of as much as 1,300 cfs (2,578 acre.ft/day) into the Qu'Appelle River (PFRA, 1979, p. 338). They indicated that the current rate of diversion does not exceed 400 cfs (793 acre.ft/day) because the downstream channel cannot handle any higher flows.

PROVISION OF THE ENTIRE MUNICIPAL WATER REQUIREMENTS FOR REGINA WOULD ENTAIL DIVERSION OF ONLY A SMALL FRACTION OF THE AMOUNT PROVIDED FOR IN THE ORIGINAL DESIGN OF THE SOUTH SASKATCHEWAN RIVER PROJECT.

3. Allocation of Costs for Water:

The capital cost of supplying water for municipal purposes to the City of Regina should be borne jointly by the provincial and municipal government. This is analogous to the water supply grants provided by the provincial government to smaller communities in the province. For example, the Town of Nokomis has recently spent about $250,000 to obtain a reliable water supply. Half of the $250,000 was provided from the Provincial Drought Assistance Program. The other 50% of the costs have been provided by the Town (population = 520) so this will work out to about $ 500 per capita. Interestingly, about 50% of the funds were spent on goods and services obtained in the Nokomis district, about 48% of the funds went for goods and services elsewhere in Saskatchewan and 2% was spent outside Saskatchewan.

A comparable investment by the City of Regina in their water supply would be about $ 75 million with about half of this money provided by the provincial government. However, 100% of the operating and maintenance cost should be borne by the City of Regina as a direct charge on the water consumed.

Alternate Sources of Supply:

In 1972 the total groundwater pumpage in the Regina area was 11,000 acre.ft/yr. I estimated that there was an additional 25,000 acre.ft/yr available for development (Saskatchewan-Nelson Basin Board, 1972, Appendix 7, p. 708). Although this water is more-highly mineralized than water from Diefenbaker Lake it is useable for many industrial purposes. It would become available for re-allocation in the Regina area if the City could obtain its entire municipal supply requirement from a pipeline.

There are no vast undiscovered aquifers or other subsurface sources of supply. The regional hydrogeological studies already completed are sufficiently detailed to guarantee that all of the major potential aquifers have been identified in the Regina area.

I hope that this material will be of use to you in deciding what to do about the water supply for Regina. I would appreciate an opportunity to meet with you at your convenience to discuss the broader issue of water in Saskatchewan. Please contact me if I can be of assistance to you.

Yours sincerely

W.A. Meneley, P.Eng.

THE ASSOCIATION OF PROFESSIONAL ENGINEERS OF SASKATCHEWAN
CERTIFICATE NUMBER
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WAM/aes
encl.

TABLE 1: Typical Water Analyses

Item	S. Sask. R. @ Saskatoon	Buffalo Pound Lake	Mallory Sprg Well Field	Nokomis Old Gallery
Calcium	43	51	119	68
Magnesium	40	26	56	25
Sodium	18	52	51	13
Potassium	2	5	N/D	3
Bicarbonate	171	228	438	227
Carbonate	0	0	0	0
Sulphate	60	134	261	100
Chloride	3	15	5	8
Sum of Constituents	337	511	930	444
Specific Conductance	408	630	N/D	575
Total Hardness	173	235	520	272
pH	8.2	8.0	N/D	7.4
Date Sampled	1974 a)	1974 b)	N/D c)	1981 d)

The concentration of constituents is expressed in mg/litre, except as noted:

Specific Conductance, microseimens/cm @25°C
Total Hardness as calcium carbonate equivalent, mg/l
pH, dimensionless
Date sampled, years, as shown

a) Inland Waters Directorate, 1980
b) Inland Waters Directorate, 1980
c) Lissey, A., City of Regina,1962
d) Meneley, W.A.&D.L.,Nokomis,1981

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APPENDIX 4

National Research Council Canada
Conseil national de recherches Canada

Prairie Regional Laboratory
Laboratoire régional des Prairies

File Reference

November 16, 1982

Mr. G. Muirhead, M.L.A.
Water Resources Commission
T.C. Douglas Building
3475 Albert Street
Regina, Saskatchewan
S4S 6X6

NOV 17 1982

Dear Mr. Muirhead:

In regard to your letter of November 2, 1982, I have been investigating the cause of the taste and odor of water from Buffalo Pound Lake. Most of this work has been done by Vivian Blok in partial fulfillment for an M.Sc. degree at the University of Saskatchewan. A comparison of the organic compounds present in Buffalo Pound water during August and December, 1981, was presented at a symposium in Finland this summer. This comparison forms the basis of the first part of my report to you. The remainder of our findings is being compiled for the M.Sc. thesis and when this is complete it will also include results from the summer of 1982 and will be a source of more information for you.

Because of the limited time my report is not comprehensive and of course our work was not undertaken to try and explain any differences between water in Regina, Moose Jaw, and the Buffalo Pound Water Treatment Plant. The second part of my report dealing with water samples obtained on August 17, 1982, is very much a preliminary one since the identities of the compounds which have been found in the water have not been confirmed. However, based on our previous experience there is a strong likelyhood that the identities of the various compounds will be substantiated.

In order to decide if there are real differences between the water at the three locations it would be necessary for us to do more analyses and to do these at least in duplicate. Since this involves a great deal of work it will be necessary for us to improve our methods substantially in order to speed up the isolation, separation, and identification of the organic compounds present in the water. Each of these three steps involves considerable time and effort and it is difficult to forecast if we will be able to complete

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them in time to analyze any odor problems which may arise in next year.

If there are any points in my report about which you are not clear, or if you need further information, please let me know.

Yours sincerely,

George P. Slater

GPS/ksw
Encl.

ORGANIC COMPOUNDS IN BUFFALO POUND LAKE

The earthy-musty taste and odor in water supplies is due to the compound geosmin or 2-methylisoborneol. Usually only one of these is present in affected water but both are produced by certain actinomycetes and blue-green algae. Both compounds have very low threshold odor levels, viz. 0.02-0.2 microgram/litre - this means that about half a teaspoonful of either compound in a million gallons of water would be detectable by most people. The actinomycetes and blue-green algae produce a variety of organic compounds in addition to geosmin and 2-methylisoborneol which may add to the taste and odor problem.

Samples of water from Buffalo Pound Lake obtained in August and December, 1981, were found to contain essentially the same organic compounds (Table I). The main difference was that geosmin could not be detected in the December sample. This is to be expected since the last bloom of blue-green algae in 1981 occurred in August and geosmin would have been flushed out of the lake or degraded by bacteria before December (geosmin is known to be degraded by certain bacillus species). However, it is of interest that a number of organic compounds are present in lake water in December. The source of these compounds is not known but there are at least two possibilities:

1. the compounds are left over from production by aquatic organisms during summer and fall;
2. even in winter there is enough activity by aquatic organisms to produce some organic compounds.

The concentrations of organic compounds in winter and summer have not been compared as our work was concerned only with identifying the compounds in the water. The identification of the compounds is a major problem simply because there are so many of them that it is not possible to separate and identify them all using a single analytical procedure. However, it is possible to do quantitative analysis for specific compounds, such as geosmin, and we will be investigating this aspect in the near future.

Several of the compounds identified in the water (indicated by an asterisk in Table I) do have tastes and odors which could reduce the palatability of water. At present it is not known how much of these compounds is required to cause a problem so that even if we determined the amounts of them we would not be able to state if they were responsible for some of the problem.

The taste and odor problem in Buffalo Pound Lake during 1981 was not as severe as in 1982. Consequently, 1981 was not a "good" year to be investigating the cause(s) of the tastes and odor. We have examined a number of water samples obtained from Buffalo Pound, Regina and Moose Jaw during the summer of 1982 when the taste and odor problem was severe. However, the interpretation of the analytical data has just begun and it will be some time before it is completed.

The water samples were collected at the Buffalo Pound Treatment Plant, the sewage plant in Regina and the pumping station in Moose Jaw. The last two samples would then be equivalent to Buffalo Pound water that has travelled throught the respective pipelines. Comparison of these water samples should indicate any differences due to passage through the pipelines. However, I must stress that our results to date (for the 1982 samples) should be regarded as tentative as we have not had time to confirm the identities of the compounds indicated in the various water samples. Also, it is desirable to compare several water samples obtained at different times before reaching any conclusions.

Water samples obtained at the three locations on August 17, 1982 were analyzed using the same procedure. The results indicate that thirty-nine of the compounds in Regina and Buffalo Pound water appear to be identical, while only seventeen of those in Moose Jaw water were also found in Buffalo Pound water. However, twenty-four of the compounds isolated from Moose Jaw water were also indicated in Regina water, but these were mostly compounds of relatively high boiling point which may not contribute significantly to odor problems. These observations may support Dr. Cullimore's suggestion that an increase in the threshold odor concentration of the water occurs during transmission through the pipelines.

Our analytical results show that geosmin is present in all three water samples although the quantity appears to be greatest in Buffalo Pound water and least in Regina water. Since geosmin is the only compound we have detected in these water samples which is known to produce the earthy-musty taste the threshold odors number of Regina and Moose Jaw water should be less than that of Buffalo Pound water. This is not in agreement with Dr. Cullimore's suggestion that the threshold odor numbers are greater in Regina and Moose Jaw than at Buffalo Pound.

The analyses of water from the three locations have also indicated that water from Regina and Moose Jaw appear to contain several polynuclear aromatic compounds (Anthracene, Phenanthrene, Pyrene, Fluoranthene, etc.) which are not present in Buffalo Pound water. Again, I would stress that the identities of these compounds have not been confirmed. If these compounds are confirmed their presence would be related to the respective pipelines.

CONCLUSION

The results of our work, though tentative, do show that there are many organic compounds in water originating from Buffalo Pound Lake, and that the potent odor-causing compound, geosmin, is present during, or shortly after, the appearance of blooms of blue-green algae. Samples of water obtained during the colder months contain similar compounds to samples obtained during the summer, except that the latter contain

geosmin. This would indicate that geosmin is the only compound responsible for the taste and odor in water from Buffalo Pound Lake. Since geosmin is the only potent odorous compound identified in water from Moose Jaw and Regina it would appear that passage of water through the respective pipelines should not appreciably affect water quality. However, it should be remembered that this observation is based on one set of analyses which have not been confirmed.

When our results are complete we may be able to give a definite answer to the question of whether the pipelines to Moose Jaw and Regina introduce other organic compounds to the water. Future work at the Prairie Regional Laboratory will be concerned with improving the analytical methods so that more rapid analyses and better identification of compounds is possible. Quantitative analyses of selected compounds will also be investigated.

George P. Slater

TABLE I. COMPOUNDS IDENTIFIED IN BUFFALO POUND LAKE WATER

ALIPHATIC HYDROCARBONS

Decane	Heptadecane	Eicosane
Undecane	Pristane	Heneicosane
Dodecane	Octadecane	Docosane
Tetradecane	Nonadecane	1-Hexadecene

AROMATIC HYDROCARBONS*

Toluene	1,3,5-Trimethylbenzene	2-Ethyl-1,3-Dimethylbenzene
m-Xylene	1,2,3-Trimethylbenzene	1,2,4,5-Tetramethylbenzene
o-Xylene	1,2,4-Trimethylbenzene	Phenylacetonitrile
	1,4-Dichlorobenzene	Naphthalene

ALDEHYDES*

Hexanal	Octanal	Decanal
Heptanal	Nonanal	Benzaldehyde

KETONES

3-Methylbutane-2-one	3-Methylheptane-2-one
4-Methylpentan-2-one	3-Methylcyclopent-2-en-1-one
Acetophenone *	Cyclohexanone *
4-Chloroacetophenone *	Heptan-2-one

OTHER COMPOUNDS

Limonene *	Nonanoic Acid	Hexadecandic Acid
α-Pinene *	Tetradecanoic Acid	

* Compounds which could add to taste and odor problem if present in sufficient amounts.

APPENDIX 5

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REGINA WATER RESEARCH INSTITUTE

September 1, 1982

Mr. G. Muirhead, M.L.A.,
Chairman, Water Committee,
Room 147, Legislative Building,
Government of Saskatchewan,
Regina, Saskatchewan.

Dear Sir:

Re: The Origin and Control of Taste and Odor Compounds present in Regina and Moose Jaw Drinking Water.

Further to our conversation of Friday, August 27th, 1982, I agreed to prepare a statement relative to the above topic.

My response is detailed in the ensueing sections of this report (R.W.R.I. Report No. 34). There are two formats. The first is in the form of three descriptive figures (pages i to vii) which present some of the major concepts in a simplified visual format with the necessary keys. The other format is a detailed analysis of the "state of the art" with respect as specifically as possible to the occurrences of the taste and odor problems in drinking water supplies. I must emphasize that the R.W.R.I. has not had a great deal of experience in this area nor has it undertaken a directed research contract in this area. We have developed through our limited internal resources some ability to isolate and count the Streptomyces and have conducted a literature study. Since this report was completed in three days, the reference sources are not included but will be available later.

Two questions have really been addressed, both relating to the eventual elimination of taste and odor problems from Regina's and Moose Jaw's drinking water. The first question put simply is "will the G.A.C. (granular activated charcoal) treatment system proposed for Buffalo Pound water definitely eliminate taste and odor problems from the drinking water in Regina and Moose Jaw". The simple answer is No, there would remain (particularly with the proposed restricted operation of the G.A.C. system to the summer) a risk of taste and odor problems occurring although on a diminished scale. The second question relates to the conveyance of Diefenbaker water to the treatment plant at Buffalo Pound. "Is it satisfactory to flow water down the existing channel to the lake or should a pipeline be built?" The answer is summarized in Descriptive Diagram 1

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(p.iii) but basically the answer would be that the pipeline would provide the most uniform quality of water usually of superior quality to that which would be obtained using a stub pipeline or direct uptake through existing facilities.

As you can readily appreciate, this report has been prepared based upon the best information available to me at this time. I would be pleased to discuss this report with you at a time of mutual convenience.

Yours sincerely,

Dr. D. R. Cullimore,
Director,
Regina Water Research Institute,
Professor of Microbiology.

DRC/no

Enc.

APPENDIX 6

BUFFALO POUND LAKE AS A SOURCE OF MUNICIPAL WATER

Prepared by:

O.K.C. Mang, P. Eng. (Sask.)

CONTENTS

Chapter		Page
1.	HISTORICAL BACKGROUND OF THE BUFFALO POUND WATER SUPPLY FOR THE CITIES OF REGINA AND MOOSE JAW	103
2.	BUFFALO POUND PROJECT DEVELOPMENT	104
3.	PLANT EXPANSION - 1958 TO 12 MGD CAPACITY	104 - 105
4.	PLANT EXPANSION - 1968 TO 24-30 MGD CAPACITY	105 - 107
5.	RAW WATER QUALITY AND ITS ECOLOGICAL SIGNIFICANACE - PAST EXPERIENCE	107 - 108
6.	BLUE-GREEN ALGAE AS THE IMPORTANT WATER QUALITY PARAMETER AND ITS SIGNIFICANCE IN WATER TREATMENT - PAST AND PRESENT	108 - 110
7.	PRESENT PLANT PRODUCTION CAPACITY	110
8.	POSSIBLE ALTERNATIVES FOR IMPROVING RAW AND TREATED WATER QUALITY	110 - 111
9.	POLLUTION OF DRINKING WATER SOURCES	111 - 112
10.	SIGNIFICANACE OF VIRAL AND BACTERIAL CONTAMINATION IN WATER TREATMENT	112 - 113
11.	ORGANIC MATTER IN THE RAW WATER - MAJOR CONCERNS	114 - 115
12.	WELL WATER SUPPLIES, TASTE AND ODOUR AND G.A.C. TAP FILTERS	116 - 118
13.	SPECIAL HEALTH CONCERNS RELATED TO SURFACE WATER SUPPLIES	118
	Virus Particles and Cyano Bacteria	118
	Algae-Toxins	119
	Botulism	119 - 120
	Giardiasis	120
	Actinomycetes	120 - 121
14.	THE OPERATION OF THE UPPER QU'APPELLE WATER SUPPLY SYSTEM	121 - 122
15.	POLLUTION IN THE UPPER QU'APPELLE	122
16.	POINT-SOURCES OF POLLUTION	123
17.	SECURITY AND PROTECTION OF A PUBLIC WATER SUPPLY SYSTEM	124
18.	PIPELINE FROM LAKE DIEFENBAKER TO THE BUFFALO POUND WATER TREATMENT PLANT	125

APPENDICES

FOOT NOTES: 126 - 128

REFERENCES 129

HISTORICAL BACKGROUND OF THE BUFFALO POUND WATER SUPPLY FOR THE CITIES OF REGINA AND MOOSE JAW

The development of the Buffalo Pound Water Supply for the cities of Regina and Moose Jaw has a history dating back many years.

Reports and historical accounts of explorations and surveys carried out as early as 1857-58 and subsequently during the years 1911, 1920, 1930 and later in 1949, all indicated that the future supply of water for Moose Jaw and Regina area would ultimately derive from the South Saskatchewan River via the Qu'Appelle. The concepts proposed in early reports involved the conveyance of water by means of an aquaduct (channel or pipeline) to supply water to the arid areas in southern Saskatchewan.

In January 1949, representatives of the Province, the City of Regina and the P.F.R.A. met to consider the serious water problems for Regina and to set up a joint committee called the Advisory Committee on South Saskatchewan Water Development to study and report on the engineering aspects involved. Moose Jaw was also considered in this study since it had already found it necessary to go to the Saskatchewan River and would be interested in a joint development that might be more adequate.

On March 19th, 1952, the cities of Regina and Moose Jaw made joint applications to the Government of Canada and the Province of Saskatchewan for assistance in the development of Buffalo Pound Lake as a source of water supply for the two cities.

Under the provisions of the Water Rights Act, the Province entered a reservation on behalf of the cities of Regina and Moose Jaw to divert 29,000 acre feet of water, such water to be delivered, stored and maintained at an adequate level in Buffalo Pound Lake by the Government of Canada through diversion storage and other necessary works to be constructed by the Government of Canada in order to meet requirements at all time of the said cities of Regina and Moose Jaw. The Province agreed to contribute $650,000

to be applied to the total cost of construction of the headworks estimated at that time at $5,150,000. The cost of supply and construction of the treated water transmission pipelines from the plant to the cities would remain the responsibilities of the cities of Regina and Moose Jaw respectively.

BUFFALO POUND PROJECT DEVELOPMENT

An engineering office was set up under the direction of the City of Regina Water Works Department to co-ordinate design engineering, the hiring of consultants, the tendering of contracts and to carry out all administrative work in what was now to become the Buffalo Pound Project.

The headworks were designed as follows:

Water would be drawn from Buffalo Pound Lake through an intake located 800 feet off shore connected by means of a 54 inch intake pipeline to the lake shore pumping station. The raw water would now be pumped by means of two vertical turbine low lift pumps (which capacities of 6 MGD) to a height of land 300 feet (90m) above lake level and delivered via a 42 inch pipeline connected to the water treatment plant located approximately two miles south of the pumping station. The water treatment plant would initially be equipped with two clarifiers rated at 3 MGD each, and four rapid sand filters to provide a total plant capacity of 6 MGD (IMP).

Treated water would be pumped from the plant clear well to the respective cities by means of their separately owned high lift pumps and pipelines and supplied to each city according to the agreed capital investment in the headworks in the ratio of 75% for Regina and 25% for Moose Jaw.

PLANT EXPANSION - 1958 - TO 12 MGD CAPACITY

The Plant commenced production in April 1955; Moose Jaw receiving the first delivery of treated water from the newly commissioned Buffalo Pound Water Supply system. By the end of 1956, after the first twenty months of operation, plant production had reached 1.38 bil. gal. of which Regina consumed 0.49 bil. gals. or 45% and Moose Jaw 0.76 bil. gals. or 55% of production.

It is to be noted that if the demand of either city is lower than its allotted share of water which the plant is able to produce at any given time, the other city may receive any excess water which would be available if required by that city. Moreover, during critical periods of high consumption, particularly during June, July and August, the water is supplied to each city on a daily basis according to the agreed share. This policy has worked well in the past and is being carried out on a continuing basis since it provides equitable distribution and plant operation flexibility, while ensuring optimum production.

In 1958, the plant was expanded by the addition of two clarifiers and four filters, thereby doubling the treatment capacity to 12 MGD. An 8 MGD vertical turbine pump was installed at the pumping station to provide additional raw water pumping capacity and flexibility in the selection of flow rates to the plant.

The capital investment on additional 6 MGD capacity by this extension would be shared on the basis of 51.5% for Regina and 48.5% for Moose Jaw. On the basis of a total plant capacity of 12 MGD, Regina could now receive 7.6 MGD and Moose Jaw 4.4 MGD. By 1966, total plant production for that year reached 2.82 bil. gals. of which Regina received 63% and Moose Jaw 37%.

It is to be noted that high-lift pumps installed at the plant for distribution to the cities at this time consisted of the following:

Regina pumping capacity - 1 - 6 MGD and 1-10 MGD Pump.

Moose Jaw - 1 - 3.5 MGD and 1 - 4.5 MGD Pump.

PLANT EXPANSION - 1968 to 24-30 MGD CAPACITY

At a meeting of the Buffalo Pound Water Administration Board in October 1966, the water supply problem of quality and quantity, was discussed. Increases in water demand by both cities over the past several years now indicated that a study and re-assessment of future water require-

ments should be undertaken as soon as possible.

On October 31, 1966, a letter was sent by O.K.C. Mang, Secretary of Buffalo Pound Water Administration Board, to the City Councils of Moose Jaw and Regina requesting estimates of their future water requirements in the next twenty years. A report by the writer dated November 28, 1966, to the Board stated that figures submitted by the two cities indicated combined demand 45 MGD by 1985. The report further stated the original design of the Headworks was based on an ultimate Lake Pumping Station capacity of 30 MGD and plant capacity of 24 MGD, and that in order to meet projected demands for 1985, a major expansion of the headworks would be required. It was also recommended that an 18 MGD pump would be required at the Lake Pumping Station to provide additional capacity and flexibility in the operation of the existing 3 units: 1 - 4 MGD, 1 - 6 MGD, 1 - 8 MGD PUMP.

A preliminary feasibility study was now initiated by the City of Regina Engineer's Department with Associated Engineering Services Ltd., consulting engineers, and co-ordinated with the plant staff to determine the optimum plant design which would provide a total capacity of 24 MGD.

Pilot studies were undertaken at the plant to provide data for establishing design criteria for chemical treatment, clarification and filtration process. Results of these studies were the basis for the decision to modify the plant using the relatively new concept of high rate separation equipment and mixed media filtration.

The modifications as outlined would not require any external plant structural additions but would involve the replacement of the internal equipment of the two original clarifiers installed in 1952 and the conversion of these two units plus the two clarifiers constructed during the 1958 extension to high rate separation equipment (tube settler system). The filters would be converted to a mixed bed designed to operate at a maximum rate of

4 gpm/sq. ft. (doubling the original design rate) while at the same time providing improved filter efficiency. By incorporating the above modifications, the capacity of the plant would be increased from the existing 12 MGD to 30 MGD.

Design and construction of the plant extension was completed in 1960. Besides internal modifications to the plant treatment units and filters, a total of twenty-two separate contracts were completed. Additional installations included the following:

- 72 K.V. power substation (plant)
- 72 K.V. power substation (L.P.S.)
- 72 K.V. power line linking the two new substations between the plant and L.P.S.
- 12 MGD vertical turbine pump for L.P.S.
- 18 MGD - 2000 H.P. pump for the City of Regina
- Supervisory System linkung the plant and L.P.S.
- Computer Data Logging System.

Additional pumping equipment was subsequently added to the Headworks. The City of Moose Jaw installed a 6 MGD vertical turbine pump in 1967 and 9 MGD vertical turbine pump in 1976. An 18 MGD vertical turbine pump was installed at the L.P.S. in 1977 replacing the 8 MGD unit which is presently in storage and can be used in the future as a spare unit to replace either the 6 MGD or the 4 MGD pumps (the original units installed in 1952 and still operational).

RAW WATER QUALITY AND ITS ECOLOGICAL SIGNIFICANCE - PAST EXPERIENCE

Raw water,at any given time, is generally related to seasonal changes of temperature, amount of sunlight, inorganic and organic content, bottom sediments, dissolved oxygen and pH. These parameters all relate to the development of eutrophic conditions in an impounded water supply such as Buffalo Pound Lake. Raw water containing high concentrations of nutrients and organic matter are conducive to biological growth and the development of algae blooms.

Excessive blooms of algae can be responsible for major ecological changes which may cause additional problems in water treatment.

A situation of this kind occurred during the summer of 1966 when dense blooms of blue-green algae persisted during the months of July thru October. In November, when the lake froze over, the normal process of aerobic decomposition commenced to break down the organic matter. The high concentration of this material caused a rapid decrease in dissolved oxygen inventory, from 12 mg/l existing before freeze-up down to 2 mg/l by mid-December. Fish cannot survive below this level of oxygen and a complete fish kill was now imminent.

By mid-January, all dissolved oxygen was consumed. Anaerobic decomposition commenced causing the production of high concentrations of hydrogen sulfied (up to 15 mg/l). Meanwhile, the chlorine demand increased steadily during this period, eventaually reaching 50 mg/l or seven times the normal dosage. When the ice went out in April, an estimated three million pounds of Buffalo Fish collected at the surface along the entire shoreline of the lake. The fish had to be removed manually by fork and then buried in various pits along the shore. This cleanup operation was carried out by the Provincial Department of Natural Resources (now called the Department of Tourism & Renewable Resources).

Although the above incident can be considered an extreme case of water quality deterioration, there is no guarantee that it could not happen again if similar ecological conditions developed.

BLUE-GREEN ALGAE AS THE IMPORTANT WATER QUALITY PARAMETER AND ITS SIGNIFICANCE IN WATER TREATMENT - PAST AND PRESENT

In the treatment of a surface water supply, the removal of turbidity and the dissinfection of water against pathogenic bacteria and viruses are two major requirements in the production of a safe drinking water. Taste and odour problems which exist before, and sometimes after treatment, are objectionable from an aesthetic point of view, but have no real health significance.

However the desire for improving the palatability of drinking water has always been a concern at the Buffalo Pound Plant and the search for a suitable method of taste and odour control has been an ongoing objective in the development of the treatment process.

If the turbidity of the raw water consists mainly of suspended organic matter such as particles of blue-green algae, treatment becomes increasingly more difficult in all stages of the process. These algae in particular present special problems because of their unique biological properties.

Water treatment related to the removal of algae has always been a challenge to the Buffalo Pound plant. Mechanical removal of algae by micro-straining was extensively tested in a pilot study carried out in 1962-64. The results, although encouraging, indicated that under optimum conditions only 60% removal of certain species of blue-green algae could be achieved. Removal efficiency was considerably reduced by the accumulation of algal slimes which tended to clog the micro-strainer fabric.

Moreover, the organic substances released into the water from the algae during the bloom, would still remain in the raw water and impose chlorine demand. The feasibility of micro straining for the efficient removal of suspended algae appeared doubtful as a solution to the algae problem.

The use of potassium permanganate as an oxidant in desliming some species of blue-green algae has proven successful but may cause color problems in finished water even at moderate dosages. It is effective under some conditions of raw water in taste and odour control.

In any case, chlorine must be used to provide a sufficient free residual in the final effluent to provide bacteriological safety in transmission and distribution systems.

The use of chlorine however, always results in the formation of toxic substances in the side reactions with organic matter and more specifically

in its reaction with blue-green algae. The products formed include volatile haloforms and other non-volatile chloro-organics. In the treatment process, it is necessary therefore to minimize the formation of these substances and still provide adequate treatment.

In the past several years, a considerable number of research programs have been carried out in the United States and Canada by such organizations as the Environmental Protection Agency, National Cancer Institute, and National Health and Welfare to determine health hazards associated with the ingestion of chloro-organics found in drinking water supplies, and their implication in the incidence of cancer.

Concerns with regard to tri-halomethane problems associated with the chlorination or organics in raw water have, over the past several years, been brought to the attention of the Department of the Environment. In July 1978, the Water Pollution Control Branch issued a report entitled: "Halomethane Study, Selected Saskatchewan Water Supplies".

PRESENT PLANT PRODUCTION CAPACITY

The quantity and quality of water which may be supplied from Buffalo Pound at the present time is dependent on the treatment capacity available. The quantity of drinking water supplied to the two cities to satisfy peak demands is limited to 28 MGD maximum. This out-put capacity cannot be exceeded if raw water quality during peak algae seasons does not improve.

POSSIBLE ALTERNATIVES FOR IMPROVING RAW AND TREATED WATER QUALITY

1. Reduce or eliminate completely all controllable nutrient sources (organic materials originating from animal wastes) which are responsible for the high level of production of algae in the lake.

These measures would gradually reduce the precursors which cause problems in treatment, and simultaneously reduce chlorine demand thereby lowering TTHM production. Present potential health risks in drinking water supplies would be greatly reduced.

2. Continue to develop better treatment processes to ensure maximum efficiences of removal of suspended and dissolved organic matter.

It should be noted that the available technologies of treatment do not solve the problems of organic removal. The need for an overall reduction or complete elimination of organic loading in the raw water source is the essential step in producing a safe and palatable, high quality drinking water for the cities of Regina and Moose Jaw.

POLLUTION OF DRINKING WATER SOURCES

Purveyors of water for municipal use are often reminded of pollution of surface water and groundwater supplies. Among the common problems cited relate to the pollution of "groundwater" by the infiltration of the aquifers of such substances as pcb's, arsenic and livestock sewage wastes, all of which potentially contaminate the drinking-water and create health hazards.

A case in point deals with aquifers in the areas east of Regina(1). Samples from these aquifers have on many occasions indicated the presence of coliform bacteria in numbers greater than the allowable. The coliform bacteria in these instances presumably have originated from livestock surface pollution which has penetrated the aquifer.

The testing of water samples taken at the well-pump discharges or samples taken subsequently from the distribution system in order to determine the presence of bacterial contamination, is a mandatory requirement under the

Health Regulations (governing any public drinking water supply for the protection of public health and safety), and must be carried out on a routine basis to prevent possible outbreak of human illness.

Thus it is obvious that surface pollution by livestock is a potential health risk to any drinking water aquifer but becomes a much greater hazard to human health when livestock wastes are allowed to flow freely into surface water courses intended as a source used for the production of drinking water. Moreover, in the latter situations, the possibility of viral contamination is of prime importance.

SIGNIFICANCE OF VIRAL AND BACTERIAL CONTAMINATION IN WATER TREATMENT

The presence of viruses (pathogenic or non-pathogenic) has always been a concern to the drinking water purveyor. To further complicate matters concerning health protection, this kind of contamination is not only difficult to identify but even more difficult to prove after the fact (cause and effect), when illness have broken out among the population. Further difficulties present themselves to the water purveyor when proper treatment of surface water becomes very difficult, especially during seasons of extensive biological activity and the suspension or dissolution of these materials in the raw water column. The possibility and probability of encapsulation of virus particles and various bacterial species in this biologically active suspended material (e.g. algal particles, sewage particles), is usually the rule rather than the exception. In the present state of the art and technology of water treatment, health protection against this kind of contamination cannot be assured because complete removal of suspended algal particles (especially during peak bloom) is virtually impossible.

The problems with virus particles are herein related to the inability during treatment of raw water, to ensure complete inactivation (disinfection) of virus, even at high dosages of chlorine and long detention times(2).

It is at this time important to note that an activated carbon filter(a) media cannot retain the above mentioned virus particles which have escaped removal during the treatment stages and therefore does not provide any additional protection to the safety of the treated drinking water. Moreover, it should be mentioned, that bacterial residues not completely inactivated during the treatment process (either free or also conceivably protected from proper disinfection by encapsulation in the algal particles) will either pass through the activated carbon media or become lodged in the microscopic pores of the carbon material and therein reside in an environment conducive to regeneration and growth.(3),(4)

The problem of treatment is now compounded further by the fact that the residual chlorine deliberately maintained in the water passing into the carbon media, will be adsorbed (b) or lost from the water (by further contact with remaining organic material which was not removed in earlier stages of treatment), thereby rendering the carbon contactor impotent in preventing bacterial growth in the micropores. The final effect is that all water having passed through the activated carbon bed must be re-chlorinated to an acceptable level of free-chlorine residual to at least disinfect the water against the usual pathogenic bacteria that may have escaped the previous extensive stages of treatment, in order that the water leaving the plant, for later distribution to the cities, will qualify at least in these parameters, under the present provincial regulations and guidelines governing bacteriological safety of public drinking-water supplies(5).

ORGANIC MATTER IN THE RAW WATER-MAJOR CONCERNS

It has been recognized by many purveyors involved in water treatment that the total organic loading in the water to be treated can be approximately related to the dosage of chlorine required to render the raw water potable for human consumption. As the organic loading increases, so will the required treatment increase, in order that the finished water (under the presently recognized criteria) will qualify as "drinking water", before distribution to the tap.

Earlier in this report, Blue-Green Algae were mentioned as an important parameter related to drinking water quality. Many of the effects of chlorination relate to the formation of Total-Tri-Hal-Methanes (TTHM's). It should be noted that the amount of organic carbon (TOC) content (not to be confused with the term "activated carbon") in the raw water, can be correlated with changes in Chlorine-Demand. This is a correlation which for several years has been established in the case of Buffalo Pound Lake Water Analyses, and confirms that most Chlorine-Demand in this particular raw water can be attributed to the total organic material, either dissolved and/or suspended, which is produced by B-G Algae and is responsible for the majority of haloform reactions (c).

Other raw waters containing very little algal material but also high in TOC (e.g. oil wastes, humic acids, bird and animal wastes, etc.), do not correlate in the same proportions of compounds formed in reactions with chlorine, even though the possible reactions available may take place, forming not only similar THM's as those produced from algal material, but additional reaction products of TTHM's still undetermined.

It should be recognized that many of the TTHM reaction products from the chlorination of B-G algal materials are related to those produced from the chlorination of sewage wastes, humic materials, and swimming pool residues. Clearly the biological materials involved in the reactions of chlorine with B-G algal and various animal waste products (including human wastes) are quite similar and therefore are capable of the production (in varying proportions of TTHM's) of many toxic substances (d) including such compounds as: chloroform, dichlorobromomethane, bramodichloromethane, 1,1,1, trichloroethane, carbon-tetra-chloride, and many others.

These volatile substances which remain substantially dissolved in the finished water, are carried along with the water through the transmission pipelines from the plant to the cities and distribution system, thence to the comsumer's tap,while at the same time often increasing in concentration because the chlorine residual maintained in the water (to provide necessary bacteriological safety) continues to react, firstly, with the remaining organic material in the water left previously unreacted during the treatment process and secondly, reacting with organic material (3) already existing in the transmission lines and previously deposited over a prolonged period of time. The above problem alone is difficult and virtually impossible to overcome except by ultimately reducing or completely eliminating the organic matter in the raw water at the source(e).

It is to be noted that the use of activated carbon would have limited effectiveness (even for a relatively short time) in removing selected amounts of the TTHM's and TOC's retained in treated water, and therefore would be virtually useless in reducing health effects due to the ingestion of TTHM's in the consumption of drinking water containing these products.

WELL WATER SUPPLIES, TASTE & ODOUR AND G.A.C. TAP FILTERS

The use of "tap-filters" has for many years been advocated as the "panacea" for improving the quality of drinking water at the consumer's tap. Indeed, "granular activated carbon" which is normally employed in these filters (readily available commercially) is the method by which the consumer is purportedly able to cope with the problem of taste and odour of tap supplied drinking water. Ironically, these filters are actually not filters at all and serve only as "contactors" to adsorb or occlude some of the taste and odour producing organic compounds contained in tap drinking-water.

Drinking-water as we know it originates from two possible sources: ground-water (well water) or surface-water (lakes, rivers, stationery open man-made reservoirs and farm dug-outs, all of which are supplied by some source of surface run-off). It should be recognized that whatever the source, all water at some point in time originates from initial evaporation from the ocean surfaces, subsequently condensing in the form of precipitation and ending up as "surface run-off" as a surface supply, or percolating into the ground aquifers as ground water; the whole process known as the hydrologic-cycle.

Not withstanding the normal pollutants in run-off (e.g. sewage and industrial wastes), many impurities such as minerals and metallic ions from various natural and man-made sources become dissolved in the freshly precipitated water, either from surface impurities or from soil strata or subterranean formations that contribute these impurities. Ground water for drinking purposes, so produced, will contain inorganic material which determines its hardness, and other inorganic natural chemical substances such assulphates, all of which provide a taste to the drinking water and therefore is most often preferred by consumers accustomed to drinking "hard-water" because of its "palatability".

However, excessively mineralized water (TDS above say 1,500 ppm) may be undesireable in many instances because of high content of such substances as iron and manganese which in themselves have no real health significance but give rise to problems of treatment when in excessive concentrations; (i.e. in most ground water supplies in Saskatchewan this becomes a major problem when iron and manganese together will reach concentrations ranging from 5 to 15 ppm)(5). Even if treatment is possible for iron removal in most well water supplies, the nagging problems associated with persistance of "iron bacteria" become the major concern to the farmer (using well water supplies) and the municipal water purveyors.

Well waters often develop very high sulphate content from some stratum in the aquifers, especially in combination with organic pollution in the ground and thus present a problem to the farmers and municipal water supplies in the form of sulphate reducing bacteria which often results in the production of excessive amounts of hydrogen sulphide. In this case, the dissolved gas emanates readily from the consumer's tap and is very difficult to remove at the source. The purported panacea often recommended for this situation is the use of the "tap-filters" which does not succeed as a solution to the problem because the inherent cause of "bacterial contamination" of the filter (home purifier) is not resolved. Therein lies one of the reasons for at least chlorinating ground water supplies affected by this biological parameter alone. In the case of excessive iron and manganese (i.e., iron bacteria) in the well supply, the treatment by super chlorination at the source is required. It should be noted that other basic important health related well water quality parameters are listed in the Provincial Guidelines (5).

Thus the problems of hydrogen sulphide and iron-bacterial growth often innundates the use of some well water supplies. In an attempt to use this water for drinking purposes from the consumer's tap, the application of a "so-called tap carbon-filter" will do nothing to remove the cause and may even augment the problem. The consumer will be required to replace the filter cartridge simply because it plugged due to the excessive iron deposits (including concentrated iron and other bacteria)and sulphate reducing bacteria and may even claim that the water still tasted satisfactorily.

Bacteriologically, the tap filter has been useless and most often creates additional hazards to health by harbouring pathogenic bacteria and other micro organisms (3) that have not been destroyed previously by the residual chlorine purportedly provided early by the water purveyor.

This is the dilemma associated with the use of "point of use purifiers" (e.g. carbon tap filters)in that they are not always effective in taste and odour control and are completely ineffective in providing health protection, while superficially (suppliers claim) providing safe, good tasting water to the consumer.

SPECIAL HEALTH CONCERNS RELATED TO SURFACE WATER SUPPLIES

Virus Particles and Cyano Bacteria:

The concerns related to pathogenic viruses involving water treatment and filtration processes have been mentioned earlier to this report. At the present time, the possibility of contamination of drinking water at the consumer's tap may be particularly relevant to surface water supplies, which due to the nature of pollution sources that purvade in the Upper Qu'Appelle pose a risk of this type of contamination.

Cyanophyceae are a division of the kingdom procaryotae that includes the blue-green algae, often called cyanobacteria. The bacterial contamination associated with those micro-organisms is always a health concern and requires sufficient chlorination during treatment of the raw water to minimize this risk. The health effects associated with the chlorination of blue-green algae was previously discussed in detail (h).

Algal-Toxins:

The toxic substances produced by blue-green algae have been of concern to the water purveyor for many years. The earliest reported cases known to the author of animal poisoning from B-G algal toxins circa 1962 near the causeway at the present crossing on the W. side No. 2 Highway Bridge, North shore of Buffalo Pound Lake, at which time two calves died of toxins produced by the B-G algae, Anabaena. Dog poisonings occur almost annually during the late summer season along Buffalo Pound Lake shoreline, some cases of which remain unreported to the veterinarians. When these cases are reported, there is usually insufficient time to take the animal to the veterinary clinic for treatment (f).

Botulism:

Botulism has been known to occur frequently in the Eyebrow Lake area but often remains unidentified or unreported. Last year (1981) alone, purportedly some 1,500 birds (ducks predominantly) were lost. Major duck-kills have been reported in Manitoba in 1980-81 resulting in an estimated loss of between 15 to 20,000 birds. Areas affected usually result from low, receeding water levels of shallow lakes, highly mineralized and stagnant.

Botulin, a highly active neuratoxin is produced by clostridium-botulinum and is peculiar in that it resists the action of gastric juice.

It occurs in six anti-genetically distinct forms called botulinum toxin. The identification of the substance requires special laboratory procedures.

Literature on the subject of botulinum toxin does not appear to be extensive. Information from Ducks Unlimited (Canada) has cited a bibliography of papers on the subject (6).

Giardiasis:

The above disease is a parasitic bowel infection which may occur in both animals and man. Giardiasis often results from the injesting of drinking water containing animal wastes (particularly from Beaver, the known animal host) of the parasite Giardia Lamblia through the transfer of the organisms themselves or their cysts being present in the improperly treated drinking water.

Random incidences of the disease have been reported in Saskatchewan from time to time. However, there are human cases in Regina of more recent discovery (that are not known to have originated from the drinking water), but have frequently been identified in humans who have migrated from other countries where the disease is more commonly found, probably because of improper sanitation.

Recently there have been cases reported in the Banff area where improperly treated water supply was implicated. Action is being taken, it is understood, to eliminate the problem probably by improving water treatment facilities.

Actinomycetes:

Actimomycetes are a genus of micro-organisms that have been known for many years, to cause problems in water treatment of surface supplies. The author was personally involved some time ago in the search for the

existance in the raw water of these somewhat illusive, but nonetheless health related micro-organisms known to be responsible for at least some of the taste and odour problems in the drinking water supplies (3).

The possible development and growth of these biologically active spore-formers (sometimes called "ray-spores" because of their branching filamentous structure) affecting many surface water supplies, are difficult to find and identify, even by optical microscopy, unless they can first be isolated and incubated by special laboratory procedures.

The continuation of propogation of these micro-organisms, once established in a water treatment facility or in a distribution system, presents almost insurmountable difficulties to the water purveyor to maintain a biologically clean system. This is reason alone which makes it mandatory first of all to identify the source of the problem before action can properly be taken to eliminate it after the fact.

THE OPERATION OF THE UPPER QU'APPELLE WATER SUPPLY SYSTEM

Water is supplied to Buffalo Pound Lake via open channel releases from the control structure located on the S.E. Arm of Lake Diefenbaker at the site of the Qu'Appelle Dam. The flow of water which is released from this source serves to maintain constant water level in Buffalo Pound Lake.

Water is released on a continuous basis the year round except for a short period of time before the spring run-off in order to allow the lake level to be lowered and thereby provide additional capacity and freeboard in Buffalo Pound Lake to absorb the spring melt run-off flows.

It should be mentioned that water is released continuously at a small rate of flow at the East causeway ofBuffalo Pound Lake. This flow while providing water for down-stream users in the Qu'Appelle Valley, sim-

ultaneously causes some movement of water through the lake and thus provides some inducement to maintain raw water quality in the lake.

During spring flood conditions, large flows originating from the Moose Jaw River (j), entering the Qu'Appelle at the confluence adjacent to the downstream side of the East causeway, have resulted in high water elevations throughout the receiving water areas (presently used by Ducks Unlimited as a water fowl production area).

Repeated flooding of this area in past years has caused water levels to rise sufficiently to spill over the stop-logs control structure and allow polluted water (k) to enter Buffalo Pound Lake from the east end. These conditions in the past have threatened raw water quality by promoting the increases of nutrients and other pollutants.(1)

POLLUTION IN THE UPPER QU'APPELLE

In planning a multi-use application of the water conveyance system, the development of the Upper Qu'Appelle involved the dedication of lands within the Valley confines for the development of confined livestock operations and grazing areas for range cattle. At the same time marsh lands and wet lands were developed for the raising of water fowl.

A major project of this kind (still in operation), the "NISCU" goose hatchery was developed. This operation was contingent on the wet land areas being fed with water from the channel through control structures strategically located along the dykes whenever required. Some of these structures were designed to release water from flooded wet lands located adjacent to the North perimeter of the dykes back into the channel (m), (carrying water downstream ultimately into Buffalo Pound Lake). This water returned into the channel through uncontrolled reverse-acting disk check valves, and contained a high level of organic contaminants, including animal and waterfowl wastes.

POINT-SOURCES OF POLLUTION

The operation of the "NISCU" project in the Eyebrow Lake area has been a contribution of waterfowl wastes. This problem was discussed early in the report and can be considered a point-source of pollution. Other point-sources related pollution by livestock operations located east of Eyebrow Lake and may ve reviewed on video tape if desired.

General pollution sources (non-point sources) exist along the north shore ofBuffalo Pound Lake from range land livestock operations.

Finally, the Rankin Marsh Development Area for Fish and Wildlife should be considered a major point-source of pollution and will be discussed in greater detail in the foot-notes.

One other point-source of pollution originated from the Hutterite Colony discharges, and this will be discussed in detail in foot-nones (n).

SECURITY AND PROTECTION OF A PUBLIC WATER SUPPLY SYSTEM

It is of prime importance to recognize there is a need for the proper protection of a public water supply. During time of emergencies it is vital to a community that a water supply can be maintained especially under "disaster" conditions: electrical storms; major power failures that could affect large and small communities alike; (as occurred in circa 1981 when a major power grid failure allected all of Saskatchewan for several hours) flood disasters; sabotage of the water source and main conveyance system of supply and delivery; toxic chemical spills and spills from major sources of pollution; nuclear disaster.

Protection of the public against many of these disaster conditions, in many instances, can be avoided by proper surveillance and inspection of vital points in the system. Protection of this kind can be provided by such agencies as the Emergency Measures Organizations (Federal and Provincial), the R.C.M.P. (i) and in the extreme cases the Armed Forces. It is important to know that most agencies mentioned above are in place and functional.

A water conveyance system is an essential requirement of any water supply system especially during times of emergency. It is obvious that a closed conveyance system such as a pipeline is much more likely to remain as an intact closed water supply system which can be more safely protected, more easily maintained, inspected, kept under surveillance and provide greater security protection against accidental spills of toxic chemicals or be sabotaged.

Finally it should be emphasized that a closed pipeline water conveyance system provides this protection to a public water supply system.

PIPELINE FROM LAKE DIEFENBAKER TO THE BUFFALO POUND WATER TREATMENT PLANT

A water supply pipeline is vital to the protection of public health and safety and is an essential requirement in providing this service in the public interest.

It is imperative that design and construction of this pipeline commence as soon as possible in order that it can be in place and functioning by 1984.

FOOT NOTES:

(a) Granular activated carbon is not technically a filter but a "contactor", meant to adsorb from the treated water many undesireable substances (not only taste and odour producing substances) in drinking water, but is completely ineffective in removing virus particles per se, either free or encapsulated in other organic matter which escaped treatment.

(b) The effect of chlorine adsorption by activated carbon has long been recognized by those involved in water treatment processes. This phenomenon has been demonstrated in the past at the Buffalo Pound Water Treatment Plant, at which time Powdered Activated Carbon (PAC) was applied to the process at various points of application. PAC can sometimes be used to reduce taste and odour of incoming raw water (which has been pre-chlorinated) or after treatment prior to filtration.

At both points of application, the function of PAC is basically the same: to reduce the organic loading by adsorption of suspended matter and reduce by adsorption taste and odour producing substances.

In the first case of application during the treatment process, suspended matter including the spent PAC, is precipitated out on a continuous basis and thence discharged to waste along with coagulated sludge. The supernatent of clarified water now passes onto the filters, the spent carbon having been removed as sludge during treatment. In this application, the contact time for bacteriological disinfection of the raw water is reduced to a minimum because of adsorption by PAC the latent chlorine residual otherwise capable of further useful oxidizing effects on the remaining organic matter.

In the application of PAC prior to clarified water (immediately prior to filtration), the intended function is to adsorb remaining tastes and odours and allow the PAC to be retained on the filter media during filtration. A reduction of the chlorine residual is again caused by the PAC, and further diminished during contact within the filter media with the result that disinfection of standard filter media (mixed sand bed) is prevented, while at the same time contact time for adequate taste and odour removal is again reduced .

Simultaneously, another problem develops: that of carbon particles (from the PAC) passing the filter into the clear-well. Experience has shown that minimum dosages of PAC, required to reduce threshold odour numbers in the finished water to an acceptable level, become excessive (greater than 15 ppm), resulting in filter penetration even before a normal headloss prior to backwashing the filter has developed, and PAC entering the clear-well will eventually end up at the consumer's tap.

Methods of detection of algal toxins are being developed so that identification and concentration in raw water can be determined. It is known that livestock poisoning from algal toxins occurs during the algae season each year, at various locations in Saskatchewan, and may result in a considerable economic loss to the farmers so affected.

(h) Various confidential reports submitted by O.K.C. Mang to the Buffalo Pound Water Administration Board, pertaining to vital concerns related to the protection of public health and safety in water supplies may be obtained by permission of the Buffalo Pound Water Administration Board through the administrations of the cities of Regina and Moose Jaw.

(i) Problems related to the protection of wildlife and domestic animals usually involve cases (accidental or otherwise perpetrated) of poisoning caused by chemical spills, bird-kills caused by botulism or other pathogens, or animal mortalities that result from B-G algal poisoning.

It is recognized that the R.C.M.P. often become involved in these cases and are, by their mandate, required therefore to investigate the cases when reported, because of implied moral, ethical and legal responsibilities affecting the loss of property (i.e. domestic animals involved) and biological disasters (i.e. a major attack of botulism) reflecting human health concerns with consequent ramifications.

Cases of this kind have occurred during the past few years. The writer has himself become personally involved in some instances working with the R.C.M.P. and the Provincial Veterinary Laboratories to help identify B-G Algae aledgedly responsible for the death of animals and later confirmed.

(j) Photos and videotape taken by the author at the time showing these flood waters entering Buffalo Pound Lake over the control structure may be reviewed on request.

(k) Livestock operations West of Moose Jaw along Thunder Creek have been major contributors of pollution from this source of flows that eventually merge with the Moose Jaw River and arrive at the confluence of the Moose Jaw River and the Qu'Appelle Valley adjacent to the flooding areas east of the East Causeway (previously described).

(l) A sample of an oil spill originating from B.A. Oil Refinery some years ago, was collected from the surface of Moose Jaw River passing below the Burdick Bridge and presently available for analysis if required.

(m) Refer to videotape showing black flow through dykes into the channel near bridge of the grid road at the east end of Eyebrow Lake.

(n) Refer to videotape showing discharges of a stream carrying animal wastes directly into the channel leading ultimately into Buffalo Pound Lake.

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(c) B-G Algal Materials react readily with chlorine because of their unique bio-chemical structures, conducive to the formation of selective species of compounds in the total THM spectrum.

(d) Many of the effects of chlorination of raw water related to the formation of TTHM products which have been cited extensively in technical literature (2) of the discipline dealing with "Environmental Impact and Health Effects" related to the above. The presently existing regulations in the "Provincial Guidelines" governing these parameters in water treatment and chlorination, do not cover adquately the critical aspects of this discipline as related to human health.

(e) Refer to proceedings of the Western Canada Water and Sewage Conference held at Regina, on September 21, 1978, regarding a statement made by the chairman of the afternoon session, O.K.C. Mang, Quote: "Undoubtedly the level of organic loading (in a raw water) is the prime determining factor in the effectiveness of treatment we are able to achieve. It would follow therefore that the quality of drinking water which we produce will depend on the quality of raw water which we are prepared to accept," end of quote.

(f) A case in point occurred in 1981 near the summer home of Jim King, along the N. shore of Buffalo Pound Lake, approximately 8 km West of No. 2 Highway Bridge. Inspection of the incident was made by O.K.C. Mang, who interviewed Mr. King on video-tape of the latter's personal description of the dog's behaviour after drinking water containing B-G Algae. The dog survived for approximately three hours.

(g) It should be noted that there are four main species of B-G Algae that are of prime concern in the Saskatchewan surface water supplies and specifically in Buffalo Pound Lake, namely: anabaena, microcystis, aphanizomenan and oscillatoria. The blooms of each species may be cyclic and may be dominant in a season in any summer period of optimum growth conditions. The first three species mentioned above have at times developed independantly, consecutively or may exist together for several bloom generations, after which time one species may become dominant and survive the others. All species mentioned are capable of producing lethal algal-toxins.

When autopsies are performed on the animals soon after the poisoning, the algal cells of the particular species responsible may be identified from stomach contents, (mainly dogs on Buffalo Pound Lake). However, the identification of the presence of a particular toxin is difficult, and further work is required in this field of research.

It should be noted that algal toxins function as neuro-muscular blocking agents reacting very quickly when taken in lethal doses. The usual symptoms observed (in dogs) indicate the dog appears excited and unsteady after returning to shore; nausea results, sometimes followed by bleeding and convulsions. Fast acting toxins are usually lethal to the dog in about twenty minutes, while others are known to survive for three or four hours, and in some cases the animals recover. Autoposies usually indicate liver damage.

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(1) Aquifer Contamination Risk Evaluation by MLM Ground-Water Engineering

(2) Water Chlorination, Environmental Impact and Health Effects, Volume 2, 1978, edited by Robert L. Jolley, Hend Gorcher and D. Heyward Hamilton, Jr.

(3) A Report on the Potential Source of the Earthy-Musty Odours in Regina-Moose Jaw Drinking Water and its Controls by Dr. D. R. Cullimore, September 1, 1982, RWRI Report Number 34.

(4) Hazards of Using Point of Use Water Treatment Devices Employing GAC., Health and Welfare Canada, December, 1980.

(5) Drinking Water Guidelines, Province of Saskatchewan.

(6) Refer to following papers related to Botulism:

(a) A preliminary Study of the Survival Value of a Functional Salt Gland in Prairie Anatidae, by F.G. Coach, July, 1964, issued by National Parks Branch of Northern and National Resources.

(b) The Most Poisonous Poison by Carl Lamanna (Current Problems in Research) reprinted from Science, September 25, 1959, Volume 130.